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MERCHANT SHIP CONSTRUCTION

MERCHANT SHIP CONSTRUCTION

Especially written for the
Merchant Navy

BY

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EXTRA MASTER

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FOREWORD.

THIS book is addressed to those who are studying for the various grades of Ministry of Transport Certificates and to all who seek a little more knowledge of the ships that they see, build or sail in.

It may seem to some persons, at first sight, that such a large subject cannot adequately be discussed in such a small space, but the value of a book usually lies rather in the quality than in the quantity of its contents. A good drawing, combined with a short but clear description, can often be made to take the place of many pages of print. Consequently, the text is here made as concise as possible and is illustrated by a number of full-page perspective drawings. To avoid confusion, only the most common method of constructing any particular part is shown, although there may be a number of alternatives.

In the chapter relating to each part, the Lloyd's Dimension governing its size is given and also details of the riveting. The reader should not, generally speaking, attempt to learn these, but they are included in order that he may form an idea as to how the sizes of parts are controlled and how such parts are built up and connected together.

In this revised edition the subject matter has been carefully examined to ensure that it conforms with current practice and with the considerable changes recently introduced into Lloyd's Register. Much has been completely rewritten, some sections have been enlarged and new matter has been introduced where this has been considered desirable.

The Author wishes to express his appreciation and thanks to Captain Wakeford for his kind interest, suggestions and assistance. Also to a number of others who must, unfortunately, remain anonymous, but who have taken an interest in the work and have made available many plans and much information on the subject.

H. J. P.

SCHOOL OF NAVIGATION, WARSASH.

1950.

INTRODUCTION

IT gives me the greatest pleasure to write the introduction to Mr. H. J. Pursey's book on the construction of merchant ships. For many years I have felt there was a great need for an authoritative book on ship construction, written especially for the sailor. I can remember many weary hours spent in trying to visualise parts of a ship from the ordinary plan, side view and elevation drawings. When I was in a ship, or more particularly a shipyard, I could sometimes see the actual parts, but when I was ashore it was a very different matter. Like many sailors, I had had no training in mechanical drawing, and it was a laborious job trying either to learn or to teach others something of actual ship construction.

Mr. Pursey's book would have solved many of our difficulties. His excellent perspective sketches give such perfect illustration of the various parts of a ship that I feel sure that ship construction will lose many of its terrors.

During the preparation of the book the various parts were subjected to the criticism of the many officers who attended University College to prepare for their certificates. It has therefore passed a representative jury of its future public.

A knowledge of the strong and weak points of a ship is more important during war than in peace, but the opportunities to acquire that knowledge are very much decreased in war-time. I am sure that this book will make the study of ship construction easier, not only for those at sea, but also for those of our brother sailors who are prisoners of war.

G. W. WAKEFORD, F.R.A.S., A.I.N.A.,

Extra Master.

*Director, School of Navigation,
University College, Southampton.*

INTRODUCTION TO SECOND EDITION.

It is eight years since this book was first published and it has proved to be as useful as I expected. Times have changed since I wrote the first introduction, but I have little to add to it.

Mr. Pursey and I hope that this new edition will prove even more helpful to the officer of the Merchant Navy.

G. W. WAKEFORD, F.R.A.S., A.I.N.A.,

Extra Master.

*Director, School of Navigation,
University College, Southampton.*

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SECTION I.

MERCHANT SHIP CONSTRUCTION.

MERCHANT SHIP CONSTRUCTION

PART I.

CLASSIFICATION OF SHIPS.

Purposes.—To ensure that ships are properly built, equipped and maintained, a number of "Classification Societies" have been formed and have drawn up rules governing the construction of ships. The Societies have surveyors, who see that the ships are built in accordance with the rules and who also survey the ships periodically, to make sure that they are kept in proper condition. Each society also keeps and publishes a "Register Book," in which all the important particulars of each ship are faithfully and accurately recorded.

Classification Societies.—There are two British Societies: Lloyd's Register of Shipping and Aircraft. These two are now associated with each other. The French society "The Bureau Veritas", also has a British Committee.

It should be remembered that the societies only classify ships and are a separate body from the underwriters who insure them.

The Rules.—The rules of the different societies vary somewhat in detail, but are mainly very similar. They are not arbitrary and other forms of construction are allowed if they give equivalent strength.

In order to avoid confusion, Lloyd's Rules have been followed throughout this Book.

Classes of Ships.—Ships built to the satisfaction of the Societies are assigned a Class, which they normally retain throughout their life, provided that they submit themselves for the required surveys and are properly maintained.

Lloyd's Rules now quote five classes :—

Class 100A All sea-going ships, built for general service.

Class 100A "for special service"—Sea-going ships built for special purposes (*e.g.* tugs).

Class 100A "for restricted service"—Sea-going ships, built for service within specified geographical limits (*e.g.* Coasting service or Channel service).

Class 100A "carrying petroleum in bulk"—Oil tankers.

Class A "for restricted service"—ships built to trade within specially sheltered waters, such as harbours or rivers, as distinct from sea-going ships.

Equipment.—A ship in which the equipment complies with Lloyd's requirements has the figure "1" placed after the class, *e.g.* 100A1. If the equipment is not in accordance with the rules, a dash is placed after the class, *e.g.* 100A—.

Equipment comprises anchors and cables, towing and stream wires and mooring ropes.

Ships Built Under Survey.—New ships which are to be classed are normally required to be built under the supervision of Lloyd's Surveyors. To shew that this has been done, a black cross is placed against the ship's class in the Register Book, thus —✠100A1.

A similar cross in red, placed against the machinery records, shews that the engines, etc., have also been built under surveyor's supervision.

Periodical Surveys.—To make sure that a ship is maintained in a fit condition to retain her class, she is subjected to annual and occasional surveys, also to special surveys at four-yearly intervals. Details of these are given elsewhere in this book.

Assignment of Loadlines.—Loadlines are assigned by the Ministry of Transport, or by the Classification Societies, acting for the Ministry.

The assignment of loadlines is not automatically included in classification, nor is it necessary for a ship to be classed in order to be assigned a loadline, provided that she complies with the Loadline Rules laid down by the Ministry of Transport.

LLOYD'S DIMENSIONS.

Purpose.—The scantlings (or sizes) of the various parts of the ship depend on her dimensions and summer draft.

The Dimensions are as follows :—

“*L*,” the length, is measured on the summer loadline, from the fore side of the stem to the after side the rudder post, or to the centre of the rudder stock if there is no rudder post. It must not in any case be less than 96 per cent of the length overall on the summer loadline.

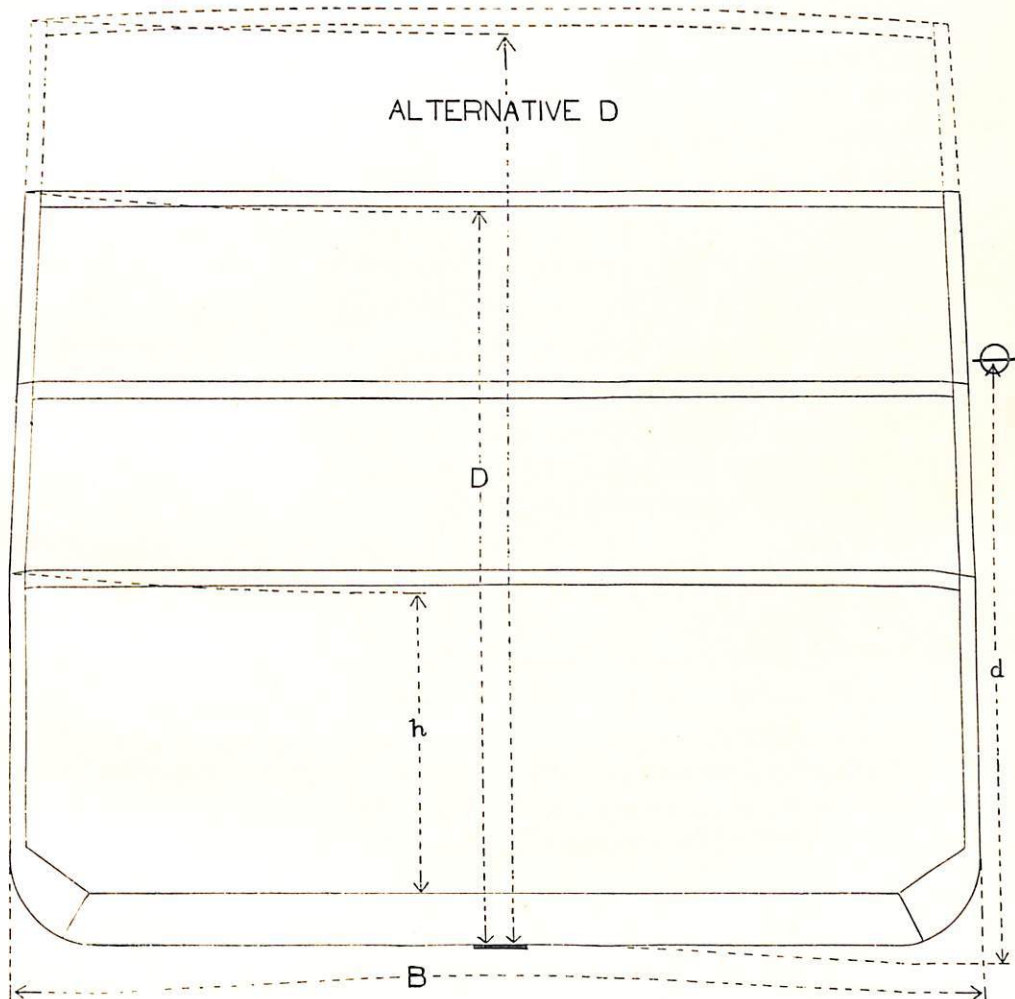
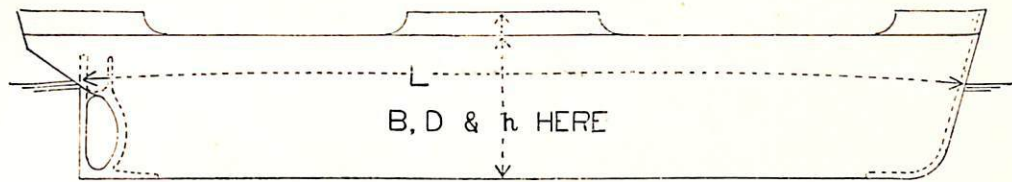
“*B*,” the breadth, is the greatest moulded breadth, measured from side to side, outside the frames, but inside the shell plating.

“*D*,” the depth is measured vertically, at the middle length of the ship, from the top of the keel to the level of the top of the beams at the side of the uppermost continuous deck : except in certain cases in which it is measured to superstructure deck beams.

“*h*,” the depth for framing, is measured vertically, at the middle length from the top of the double bottom to the level of the top of the beams at the side of the lowest deck.

“*d*,” the draft, is the summer moulded draft, measured in feet.

Note.—Throughout this book, the dimensions governing the scantlings of any part are given in the first paragraph of the section describing that part. Where the size of a part is governed by other factors, it is stated in the text.



LLOYDS DIMENSIONS.

CONNECTIONS.

General.—The various parts of a ship must be properly connected together if the ship is to be strong and rigid. The strength of any connection should, so far as possible, be equal to the strength of the parts connected.

The forms of connections described here are the more important ones in general use. Where others are used in special parts, they are described in the sections relating to those parts.

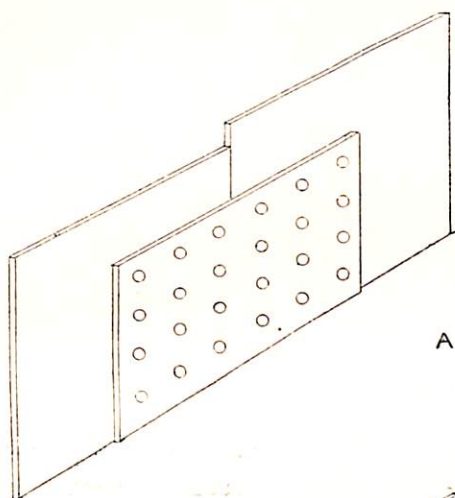
Single Strapped Joint (Sketch A).—This is one method of joining the ends or edges of two plates together. It does not give a really satisfactory joint, as it tends to open under stress and is very liable to corrosion. The short joining plate is usually known as a “Butt Strap.”

Double Strapped Joint (Sketch B).—This is a very strong joint, but is heavy and expensive to construct.

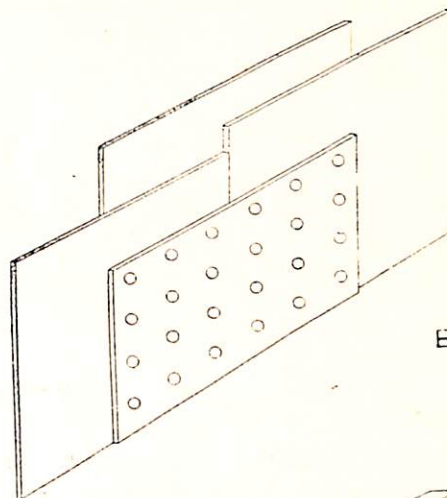
Lapped Joint (Sketch C).—Lapped joints are used almost exclusively when possible. They are not so strong as double strapped joints, but are stronger than the single strapped ones and have many advantages over both types.

Scarphed Joint (Sketch D).—The parts of a scarphed joint are connected by tapering the ends and then riveting them together. The type of scarph shewn is used mainly for bars, such as stems, bar keels and sternframes.

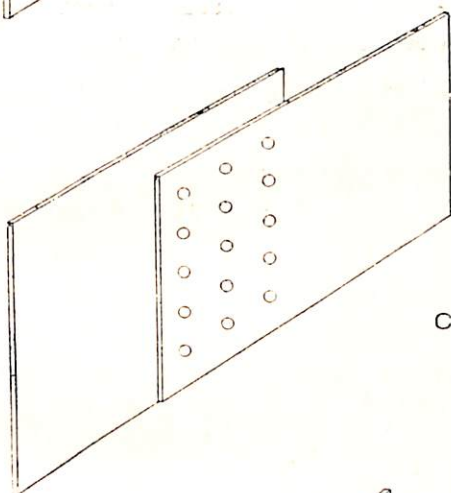
Joints of Angles (Sketches E and F).—When two lengths of angle bar have to be connected together, they are usually joined by a short length riveted to them. This length should be connected to the main bars by at least three rivets on either side of the joint. When it is fitted as shewn in sketch E it is called a “bosom piece”; when fitted as in sketch F it is called a “back piece.”



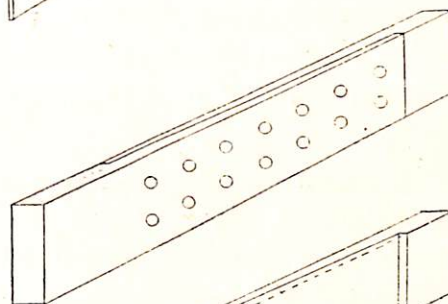
A



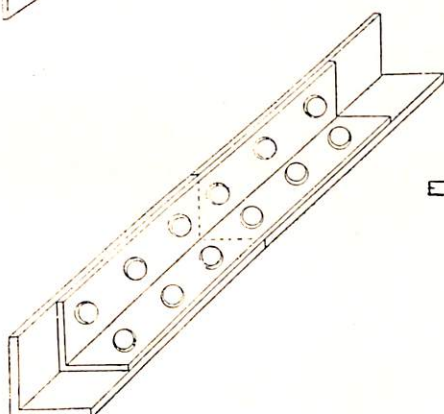
B



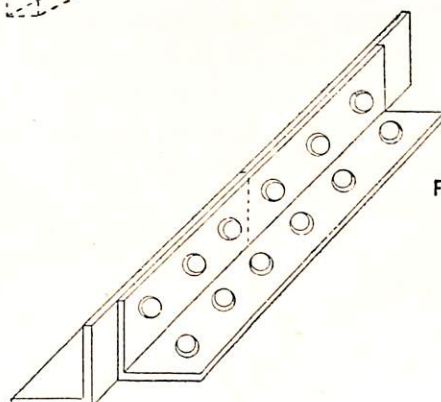
C



D



E



F

CONNECTIONS.

CONNECTIONS—(Continued).

Liners (Sketch G).—Liners are often used to fill in small spaces between two parts which are riveted together. They are largely used between out-stakes of shell plating and frames, and between deck plating and beams.

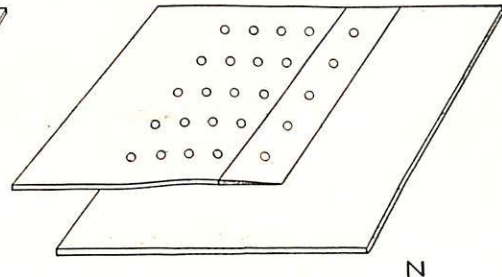
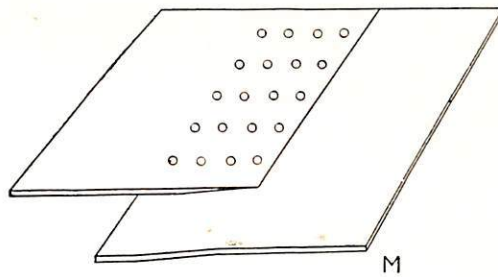
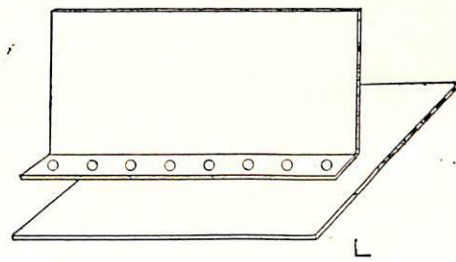
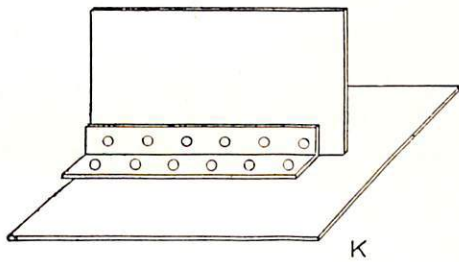
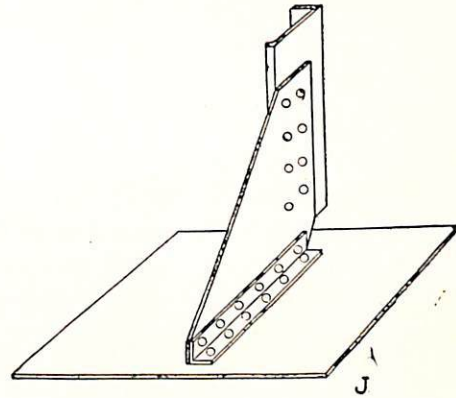
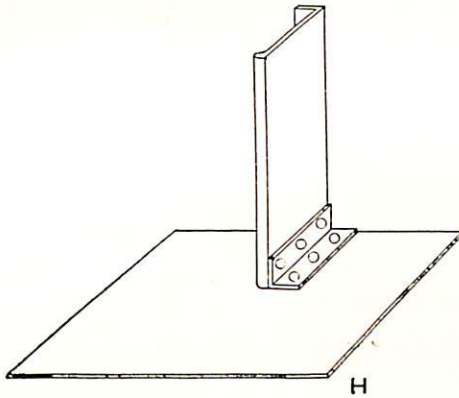
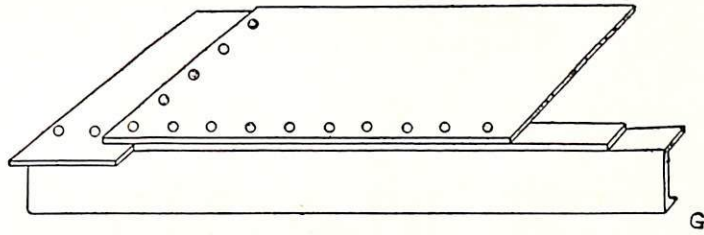
Lugs (Sketch H).—Lugs are short pieces of angle connecting parts together.

Brackets (Sketch J).—These are flat plates, roughly triangular, connecting parts together. They may be riveted directly to other parts, or may be connected to them by angles or flanges.

Angles (Sketch K).—Angle bars are often used to connect the edge of one plate to the flat of another.

Flanging (Sketch L).—The edge of a plate is sometimes flanged to do the work of an angle connection. This saves a little material and riveting, but is not so strong or rigid as the angle connection.

Level Surfaces (Sketches M and N).—It is sometimes desirable to have a flat surface on one side of a joint for connecting other parts to it. This may be accomplished by scarphing the end of one of the plates (sketch M), or by fitting a tapered liner (sketch N).



CONNECTIONS.

CONNECTIONS—(Continued).

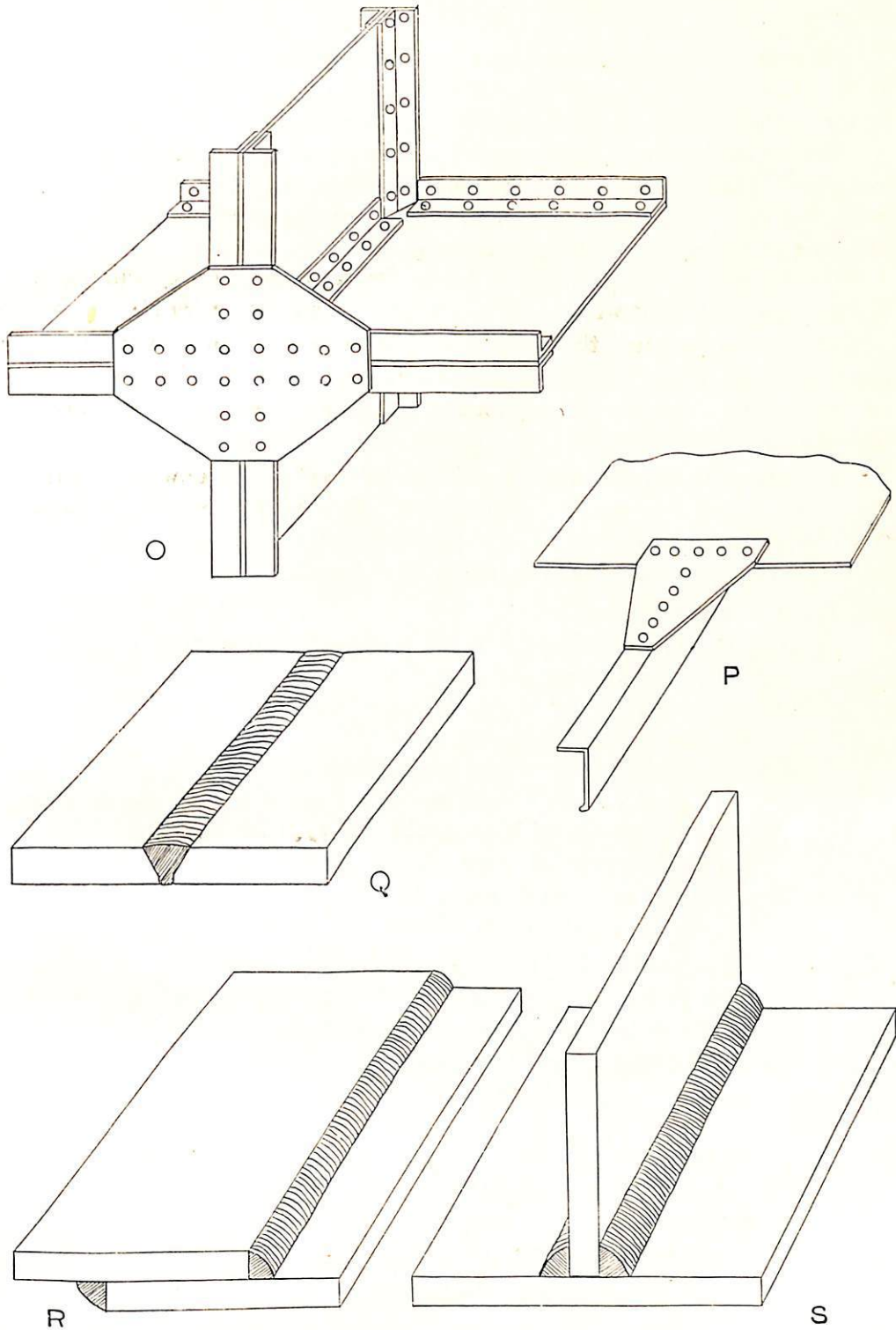
Face Straps (Sketch O).—These are often used to connect the face bars of web frames and stringers and for similar connections. There are several types, but the best known are the “diamond plate” and “half-diamond plate.” The diamond plate is shewn in the sketch.

Gussets (Sketch P).—These are very similar in form and purpose to face straps, but are used to connect plates to the edges of beams, brackets, etc.

Welded Butt Joints (Sketch Q).—Such joints are made by welding the edges of two plates together, so that they form, in effect, one continuous plate. These joints are very efficient if they are properly made.

Welded Lapped Joints (Sketch R).—The plates are overlapped, in the same way as for a riveted joint and are welded as shewn. These joints are not considered to be as efficient as butt joints, but are useful for certain purposes.

Welded T-Joints (Sketch S).—Used when plates or bars have to be joined at right angles. This type of joint is very useful for joining angle bars to plating; as, for instance, connecting stiffeners to bulkheads.



CONNECTIONS.

RIVETING.

Strength.—Riveting should have, as nearly as possible, the same strength as the parts it connects together. The work must be closed efficiently ; that is, the surfaces must be brought close together.

Each time that a hole is punched in a plate to take a rivet, the plate is weakened. Hence, rivets must not be too closely spaced or the plate will be made too weak. Rivets must not be within one diameter of the edge of the plate, or they may tear through that edge.

On the other hand, rivets must not be too far apart, or they will not close the work properly and will also be too weak to stand up under stress. Where a joint is to be caulked, the rivets must not be too far from the edge of the plate, or the caulking may force the plate edges apart.

The rivets must also fill the holes in the plates properly, or the joint will be weakened.

The Standard Rivet.—A standard form of rivet is laid down and has the shape and dimensions shewn in the sketch. Note that it is tapered for part of its length, in order to make a close fit with the rivet hole which is also tapered. This gives more holding power to the rivet.

Types of Rivet Heads.—

Pan Head is used where strength is required and is the standard form. It is usually finished flush.

Snap Head is usually associated with hydraulic work and is generally finished with a snap point.

Countersunk Heads are used where a flush surface is required. They are good for watertight work, but have several disadvantages and the pan head is preferable where it can be used. Countersunk rivets are often used in stems and similar bars.

Tap Rivets have a part of the shank threaded and are screwed into tapped holes by means of a square projection on the rivet head. They are used where through riveting is impossible, as for fastening plates to large castings. After the rivet has been screwed in the square projection is cut off, leaving the surface flush.

Method of Riveting.—The rivets are heated and pushed into the hole. The head is held up by a hammer whilst the point is hammered up.

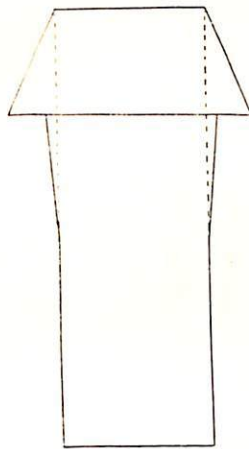
Points.—

Countersunk Points are the most common and are very efficient.

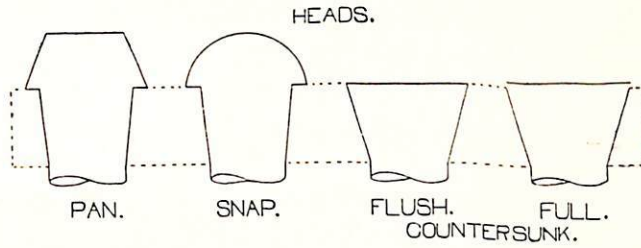
Snap Points are usually associated with hydraulic work.

Boiler Points, sometimes called "hammered points," are very strong and are often used where a flush finish is not required.

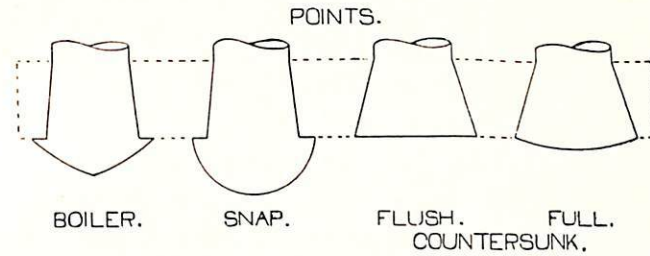
Materials.—Iron rivets were used exclusively at one time, but mild steel rivets are now very largely used.



STANDARD FORM.



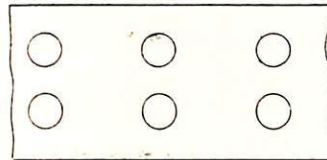
HEADS.



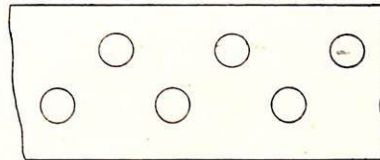
POINTS.



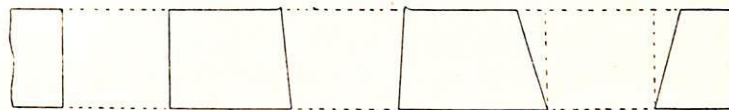
TAP.



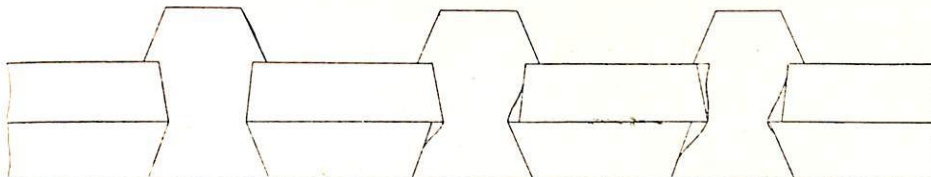
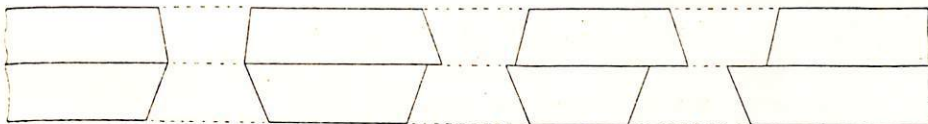
CHAIN RIVETING.



ZIG-ZAG RIVETING.



DRILLED HOLE. PUNCHED HOLE. COUNTERSUNK HOLE.



FAIR AND UNFAIR HOLES WITH RIVETING.

RIVETING.

High tensile steel rivets also exist for use with high tensile steel plates. These plates are not, however, fitted in the ordinary merchant ship.

Size.—The size of rivets is governed, with some exceptions, by the size of the thickest part they connect. The sizes required by Lloyd's Rules for general work are :—

<i>Thickness of Plate.</i>	<i>Diameter of Rivet.</i>
Not more than .36"	$\frac{5}{8}$ "
.36" to .50"	$\frac{3}{4}$ "
.50" to .72"	$\frac{7}{8}$ "
.72" to .94"	1"
.94" to 1.14"	$1\frac{1}{8}$ "
1.14" to 1.26"	$1\frac{1}{4}$ "

Rows of Rivets.—Single riveting is not considered to be very efficient, but is strong enough for many purposes. Where it is not strong enough, from two to five rows of rivets may be used. The number of rows fitted depends on the work the joint has to do and on the thickness of the plate.

Seams may be single, double or treble riveted. End laps may be from double to quintuple riveted.

Chain riveting is required for double or treble riveted joints and for all end laps of shell plating. Zig-zag riveting is permitted in other joints and also in connections to stems, stern frames and bar keels, if desired.

Consecutive rows of rivets are not to be closer than $2\frac{1}{2}$ diameters for edge laps ; 3 diameters for butt straps ; and $3\frac{1}{2}$ diameters for end laps.

Width of Laps, etc.—The width of the overlap of plates is governed by the Rules. It depends on the size of the rivets and on the number of rows fitted. End laps are wider than seams for the same riveting.

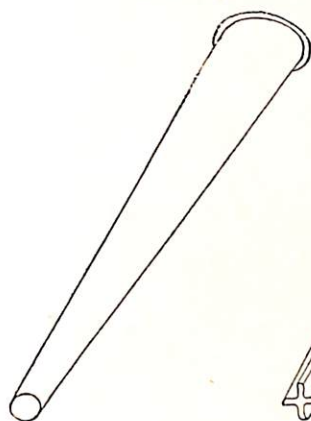
The width of the flanges of angles is to be at least 3 times the diameter of the rivets for rivets of under 1 inch diameter, and $3\frac{1}{2}$ times the diameter of the rivets for larger rivets.

Spacing.—The rivet spacing for the various parts of ships may be found in this book under the sections relating to those parts. One or two general rules are, however, worth remembering.

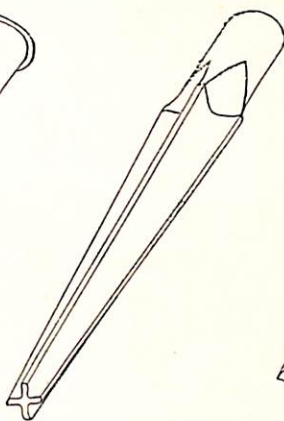
Rivet spacing should never be less than $3\frac{1}{2}$ diameters, nor more than 7 diameters.

The rivets in watertight and oiltight joints should be close enough together to resist the opening action of caulking and pressure. Watertight joints should have a spacing of not more than 4 diameters. Oiltight joints should have a spacing of not more than $3\frac{1}{2}$ diameters.

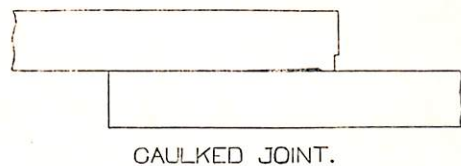
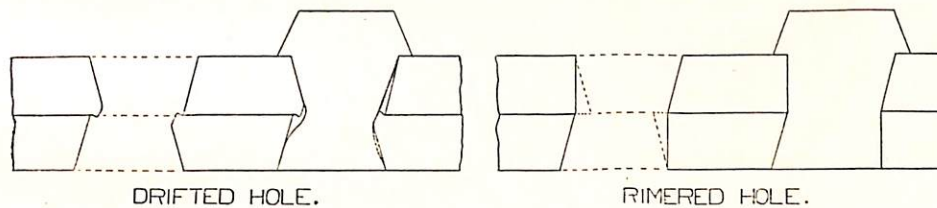
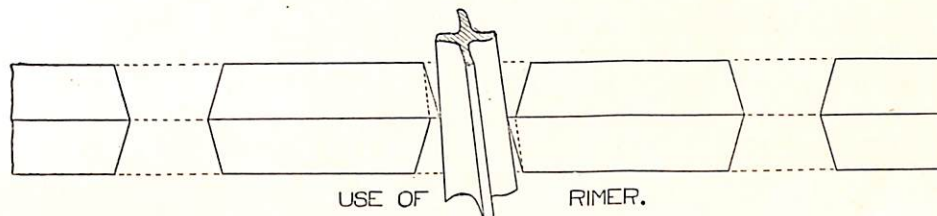
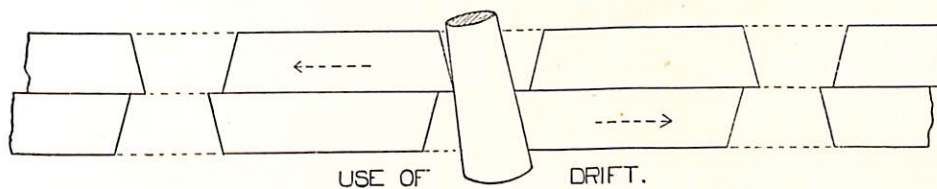
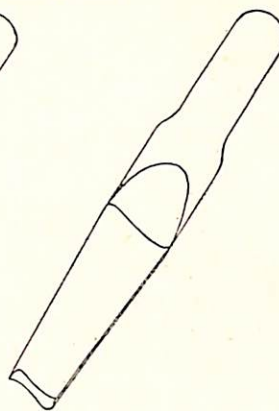
Tests.—The bars from which rivets are made must be tested before manufacture. Steel bars are to have a breaking strength of from 26 to 30 tons per square inch. Iron bars are to have a breaking strength of from 21 to 25 tons per square inch.



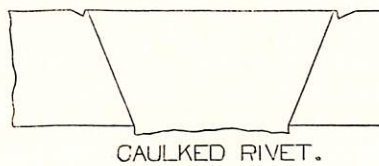
DRIFT PUNCH.



RIMERS



CAULKED JOINT.



CAULKED RIVET.

RIVETING.

After the rivets have been manufactured a number of them are to be tested as follows:—

- (a) The rivet shank is to be bent double when cold, and no fracture is to show on the outside of the bend.
- (b) The rivet head, when hot, is to be flattened until its diameter is $2\frac{1}{2}$ times that of the shank. It must then show no cracks at the edge.

Holes for Rivets.—Holes in plates may be either punched or drilled.

Punching produces a slight taper which is sufficient to hold the parts together in much ordinary work. It has a tendency to strain the metal around the hole and also leaves a “rag,” or rough edge, on one side. These disadvantages are not serious, however, and punching is very largely used, as it is quick and cheap. Lloyd’s Rules lay down that when holes are punched, they are to be punched from the faying surface (that is, the surface which bears against the other) and that any “rag” is to be removed after punching.

For watertight and oiltight work, punching alone does not give sufficient taper to the holes, which must be countersunk. The Rules require the countersinking of all holes in shell plating, weather decks, inner bottoms and peak and deep tank bulkheads.

Holes which are to be countersunk are often drilled, as this can be done quite quickly by modern machinery and avoids the strain and rag left by punching. A drilled hole has parallel sides and hence little holding power; but if it is to be countersunk afterwards, this does not matter.

Fair and Unfair Holes.—In good work the holes in the parts to be riveted together should correspond exactly. If they do not do so, faulty riveting may result, as shown in the sketch.

Holes which correspond are termed “fair holes,” whilst those which do not do so are termed “unfair,” “blind,” or “partially blind.”

Unfair holes must be cleared before rivets are put into them. The tools which are used for this purpose are Rimers and Drift Punches, each of which has its own use and should not be used to do the work of the other. The drift punch should be used where holes have been punched correctly, but where the plates have not been put together quite truly. In other words, it is used as a sort of lever to “square up” the plates. The rimer must be used where one or two holes of a row are not correctly punched. It is a cutting tool and is put into the hole and turned around until the protruding edges have been scraped off.

Caulking.—Joints and rivets in watertight or oiltight work must always be caulked. This requires skilful and careful work.

Plates and bars are caulked by cutting into them with a special tool, so as to drive a small piece of steel from the edge hard up against the other surface. Parts which have to be caulked are arranged, wherever possible, so that the caulking edge faces upward, or to the right, in order that the workman can use his tools on them the more easily. Where edges which would normally finish flush with each other are to be caulked, one is stopped a little short of the other to facilitate the work (as in the connection of the garboard strake to a bar keel).

Rivets are usually caulked by cutting into the plate around the rivet, so as to drive a small piece of steel hard up under the rivet head.

WELDING.

Ordinary Welding.—Ordinary welding is done by heating two pieces of metal until they are white-hot and then hammering them together. A “flux,” consisting of sand or borax, is put on the surfaces in order to prevent oxides of the metal from forming and spoiling the joint.

This type of welding is still used for small parts, such as watertight collars and sharp bends in angles. It is very strong if properly done.

Oxy-Acetylene Welding.—The oxy-acetylene blowpipe is chiefly used for cutting, but it may also be used for welding.

In welding, the edges of the parts to be joined are kept about $\frac{1}{8}$ inch to $\frac{1}{4}$ inch apart and are heated by the blowpipe. A swedish iron rod is then held in the flame and the molten metal drips into the crack to form a solid joint.

Electric Arc Welding.—One wire from an electric supply is connected to the work, whilst the other is connected to a swedish iron rod, which is called an “electrode.” The rod is allowed to touch the work and is then withdrawn for a short distance. This creates an electric arc, the heat of which melts the electrode and the plate edges, forming a pool of molten metal, which later cools to form a solid joint. To prevent the molten metal from becoming oxidised, the electrode is covered with a “flux” of some material which melts with the electrode and which runs down to form a protective coating over the joint while it cools.

ELECTRIC ARC WELDING

Preparation of Work for Welding.—It is most important that the work be properly prepared and particularly that all surfaces are dry and thoroughly clean.

Building-up of Welds.—In hand welding, it is not usually possible to deposit enough metal to fill the joint in one operation. In this case, a continuous layer of weld-metal, called a "run" is first deposited all along the bottom of the joint. The "slag," or protective coating of flux, which forms over the top of this run, is then removed and a second run is made on the top of the first. This is repeated until the joint has been completely built up.

Types of Weld.—

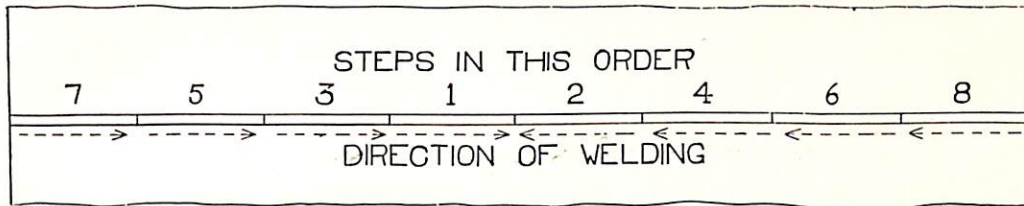
Butt Welds are usually prepared by chamfering-off, or "Veeing" the plate edges, so that the angle between them is about 60° and by spacing the plates so that there is a small gap between them at the bottom of the "V." A series of runs of welding is made on the Veed side and when this has been completely filled-in, one run, called a "back run," is made on the other side of the joint. In the figure, the runs are numbered in the order in which they are made, whilst B indicates the back run.

Fillet Welds are used for making T-joints and lapped joints. The leg length ("L" in figure) is governed by the thickness of the abutting part of the joint, whilst the throat thickness ("T" in figure) must be at least 70 per cent of the leg length. Fillet welds may be continuous or intermittent.

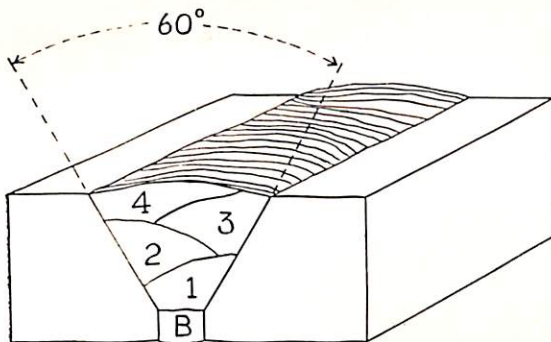
Double Continuous Fillets are used for specially important structural connections and for watertight and oiltight work.

Intermittent Fillets are used for many joints which are not required to be watertight. The length of each fillet must not be less than 3 inches and their spacing, centre to centre, may be between four and seven inches, according to the work which the joint is required to do. At the ends of structural joints, the fillets must be doubled and carried around the ends. Chain intermittent fillets are used for the more important connections and staggered intermittent fillets for others.

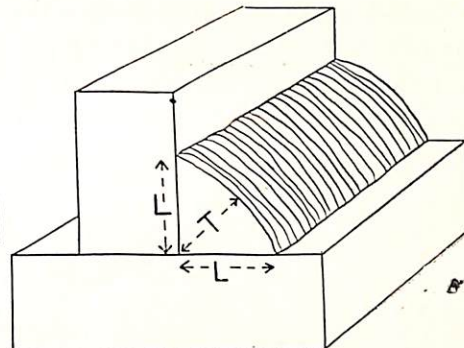
Tack Welds are spots of welding, placed at intervals and used to hold parts temporarily in place whilst a proper welded joint is being made.



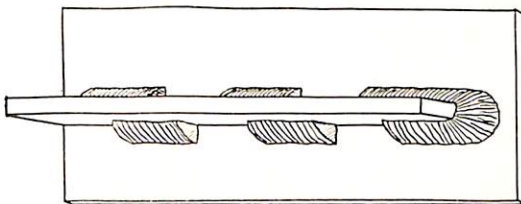
STEP-BACK WELDING



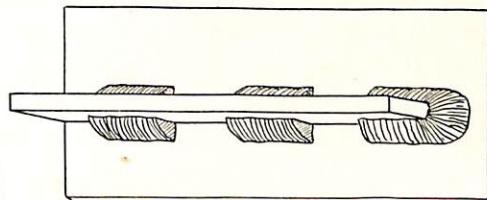
BUTT WELD



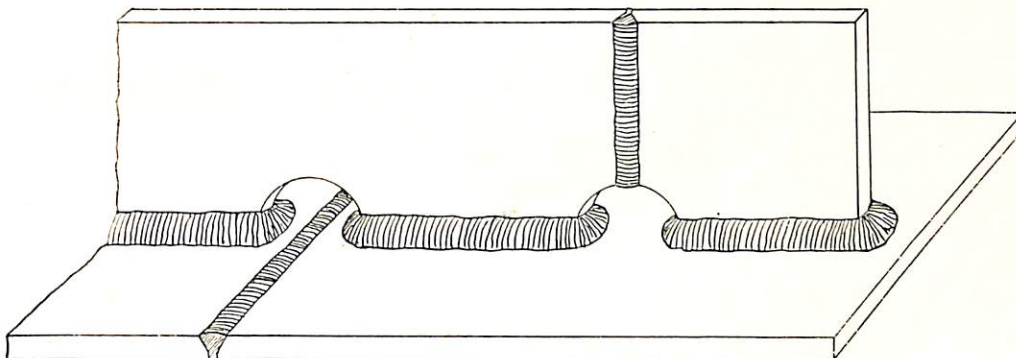
FILLET WELD



STAGGERED INTERMITTENT



CHAIN INTERMITTENT



SCALLOPING AT CROSSING WELDS

ELECTRIC ARC WELDING.

Possible Defects.—Arc-welded joints are liable to a number of defects, which may be roughly divided into two general groups :—

- (a) Defects of workmanship, which may be avoided by skilled and careful workmanship.
- (b) Distortion effects, due to the intense local heating, which may be minimised, but which cannot usually be entirely eliminated.

Defects of Workmanship.—Weak or faulty joints may be produced if the welder does not use the proper current, electrode or length of arc. These all vary according to the thickness of the metal and the type of joint which is to be made.

If the current be too great, a groove may be burned in the plate near the joint. This is called “undercutting” and it weakens the plate at a very dangerous point. Too great a current, or too long an arc may also cause some of the metal of the joint to become oxidised. This may render the joint brittle and weak, or it may cause small cracks within it.

Too small a current may cause poor penetration, or a coarse-grained structure of the weld-metal, either of which will weaken the joint. “Penetration” is the name given to that depth of the plate which has become melted and combined with the weld-metal.

It is very important that the weld should be finished-off properly, otherwise the joint will always be weakened. The surface must always be smooth and must come to the proper level. The ends of joints, in general must be carried right out and finished-off square, otherwise it is possible for a small crack to start there and to “grow” down the joint. In the case of T-joints, the weld should, whenever possible, be carried right around the ends of the joint, for the same reason.

When a joint is built up of several runs of welding, the slag must be completely cleaned off the top of each run before the next one is made. If this is not done properly, a certain amount of slag may be left in the joint, causing weakness or small cracks.

Distortion Effects.—The chief cause of distortion is the intense heat set up by the electric arc, as it melts the electrode and the edges of the work. The surrounding metal is also heated and expands, so that the edges being joined are actually a little closer together than they were when cold. After the joint has been made and has cooled, the plates on either side of the joint try to move slightly towards each other. If they are free to move, they will do so and they may also buckle to a slight extent, so that visible distortion may occur.

Distortion Effects—(Continued).—

Some of the stresses causing this will remain in the joint, for various reasons, and these are known as "residual stresses." Thick plates, or those which are held firmly so that they cannot move, may not be able to buckle or to "take-up" in this way. The stresses trying to make them do so will still exist and will remain locked in the joint, in which case they are known as "locked-up stresses." These stresses may also occur in joints which have been badly prepared, where considerable force may be required to pull the parts into their proper positions. When such parts are welded up and the restraining gear has been removed, the stresses will be transferred to the joint. Both residual and locked-up stresses weaken the joint and the metal around it. They cannot usually be entirely eliminated, but great care is necessary to make sure that they are kept to a minimum.

Residual and locked-up stresses can usually be kept within safe limits, if certain rules are observed. Residual stresses are reduced by starting from the middle of each joint and working outward to the edges, using what is known as "step-back" welding. Locked-up stresses are minimised by planning the work so that at least one of the parts being joined is free to move, each time a joint is welded. When this cannot be done, the work should be arranged so as to reduce restraint to a minimum.

General Rules.—Welded joints are very rigid, compared with riveted ones and allowance must be made for this fact. Many practices which are allowable with riveted joints, must be avoided with welded ones.

There must be no sudden changes of strength near a welded joint and square corners must always be avoided.

Welding and riveting must not be intermixed in the same connection.

Welds should never be allowed to cross each other if this can possibly be avoided. Butts which cross seams should be staggered clear of each other at the seam. The vertical arms of T-joints should be scalloped (or cut-out, whenever possible, where they cross a seam, or where butt joints are made in them.

GENERAL TYPES OF SHIPS.

General Note.—The types described in this section and shown in the sketches are the actual form of the main part of the hull. Their appearance may be altered by superstructures, but the form type will remain the same. For example, a shelter decked ship may have a forecastle, poop and bridge deck, which will give her the same appearance as a three-island ship.

Flush Decked Ship.—This was the original type in which the upper deck was also the freeboard deck.

Three-Island Ship.—In the early steamships, it was found necessary to raise the machinery casings in order to protect the engines from the sea. This led to the raising of the hull amidships, to form a bridge. The poop was also raised to protect the steering gear and the forecastle to house the crew and to help to keep the ship dry.

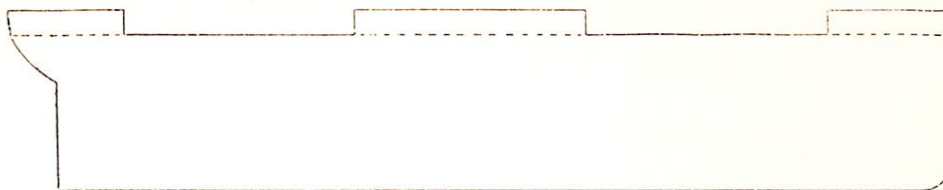
Long Bridge Ship.—Often called a “well-deck” ship. To give additional cargo space, one of the well-decks, either forward or aft, was enclosed.

Shelter Decked Ship.—The final development was to enclose the other well-deck in the long bridge ship. This gave the shelter decked ship, with a continuous upper deck which was not entirely protected from the entry of the sea. This type is being built considerably to-day.

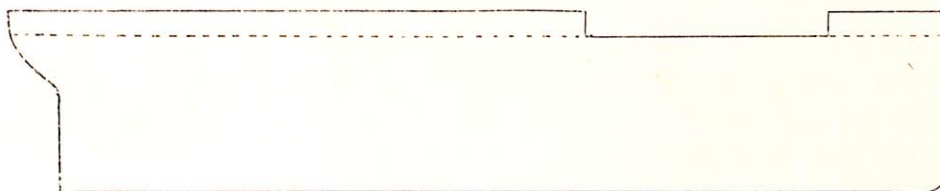
Ships with Raised Quarter Decks.—It was found that in small screw steamers the shaft tunnel took up such a large proportion of the space in the after holds, that the ship trimmed by the head when fully loaded. To overcome this the after deck was raised for the whole or a part of its length. The raised quarter deck is not seen to-day in large ships, but is still used in small ships, such as coasters.



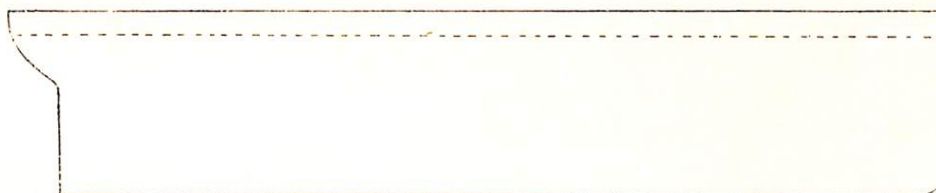
FLUSH DECKED SHIP.



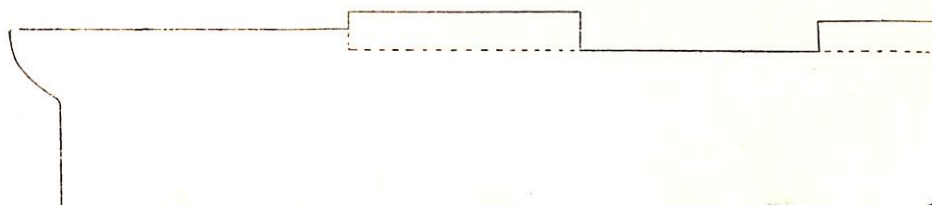
THREE ISLAND SHIP.



LONG BRIDGE SHIP.



SHELTER DECKED SHIP.



SHIP WITH RAISED QUARTER DECK.

TYPES.

SHIP WITH ORDINARY FLOORS.

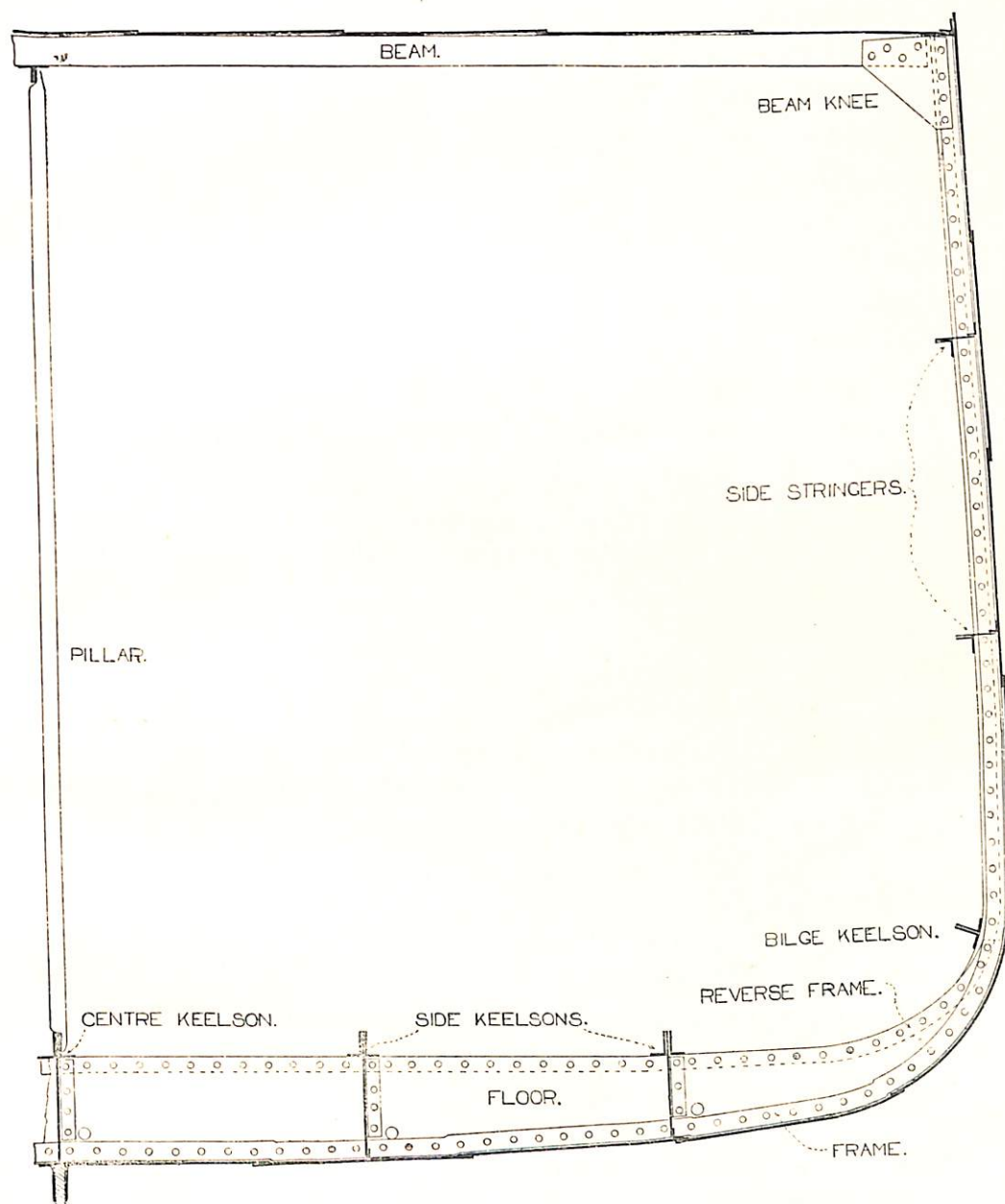
General.—The sketch shews a ship with ordinary floors, often called “open floors.” The type shewn in the sketch was the early arrangement, which was used for all ships in the early days of iron and steel shipbuilding. The system shewn here has been replaced by the cellular double bottom for all large and moderate sized ships and modified for small ships. It is included to shew the development of the various parts.

Framing.—The framing was the frame and reverse type, which was sometimes reinforced by web frames at wide intervals. The frame and reverse separated at the bilge, but were then carried right across the ship, the frame along the bottom of the floor and the reverse along the top.

Floors.—The floors were carried right across the ship. In the early type, as shewn, the frames were usually curved upwards at the ends and extended up the ship's side to a height of twice their depth at the centre line.

Side Stringers.—These were originally fitted for two purposes : to give strength and to prevent the frames from tripping. It has been found, however, that they actually gave very little strength, whilst the modern sections used for frames are so rigid that they have no tendency to trip. Side stringers have consequently disappeared as a general system and are no longer quoted in Lloyd's Rules.

Other Parts.—Details of other parts will be found elsewhere in this book.



SHIP WITH ORDINARY FLOORS.

MERCHANT SHIP CONSTRUCTION

MODERN CARGO SHIP.

The sketch shews a half-midship section of a modern cargo ship, having a cellular double bottom and massed pillaring. The following is an example of the scantlings for an average ship of this type.

Tonnage about 6600 tons gross ; 4100 tons nett.

Displacement about 13,000 tons. Deadweight about 9,000 tons.

Dimensions : L 450' ; B 58' ; D 35' ; h 22' ; d 28'.

Keel plate : 53" $\times$.86".

Central girder : 46" $\times$.54".

Side girders : .38" thick.

Floors : .42" thick.

Margin plate : 40" $\times$.53".

Margin angle : 3 $\frac{1}{2}$ " $\times$ 3 $\frac{1}{2}$ " $\times$.54".

Tank side brackets : .47" thick, to extend to 71" above the base line.

Gussets : fitted at every frame.

Inner bottom plating : Middle line strake, 54" $\times$.52".

Other strakes, .44" thick.

Frames : Bulb angles, 12" $\times$ 3 $\frac{1}{2}$ " $\times$.59".

Frame spacing : 30".

Beams : At upper deck, bulb angles, 8" $\times$ 3 $\frac{1}{2}$ " $\times$.56".

At 'tween deck, bulb angles, 9" $\times$ 3 $\frac{1}{2}$ " $\times$.51".

Beam knees : At upper deck, 20" deep, 14 $\frac{1}{2}$ " overlap on beam, .36" thick.

At 'tween deck, 22 $\frac{1}{2}$ " deep, 16" overlap on beam, .39" thick.

Shell plating : Keel to upper turn of bilge, .68" thick.

Upper turn of bilge to sheerstrake, .66" thick.

Sheerstrake : 62" $\times$.95".

Deck stringer : At upper deck, 62" $\times$.81".

At 'tween deck, .35" thick.

Deck stringer angle : At upper deck, 7" $\times$ 7" $\times$.81".

At 'tween deck, 3 $\frac{1}{2}$ " $\times$ 3 $\frac{1}{2}$ " $\times$.36".

Deck plating : At upper deck, .68" thick.

At 'tween deck, .36" thick.

Pillars : Tubular, 2 on each side of hold.

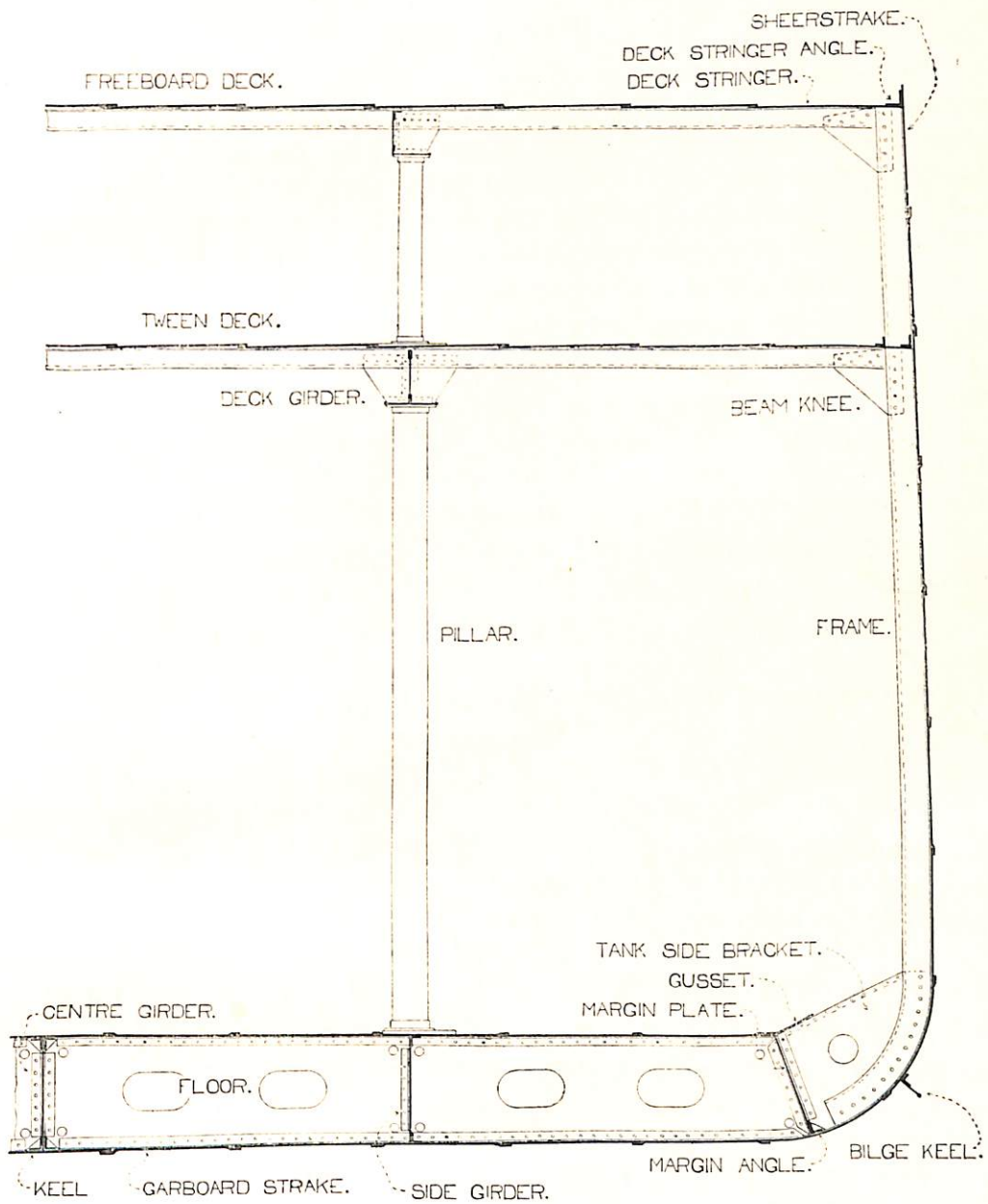
In lower hold, 14" diameter, .58" thick.

In 'tween deck, 8" diameter, .40" thick.

Deck girders : Intercostal plates, stiffened by bulb angles.

In lower hold, plate 15" $\times$.36", two 10" bulb angles.

In 'tween deck, plate 12" $\times$.34", one 12" bulb angle.



MODERN CARGO SHIP.

SPECIAL TYPES.

Passenger Ship.—The general arrangements of an ordinary passenger ship are necessarily rather different from those of an ordinary cargo ship. Their general construction is the same, except that in the passenger ship the passenger decks are always sheathed with wood, or covered with some suitable composition, whilst the arrangements at the bilge are different. Details of the latter can be found on pages 48 on 49.

This does not apply to very large passenger ships, which must have special structural arrangements to give them the necessary strength.

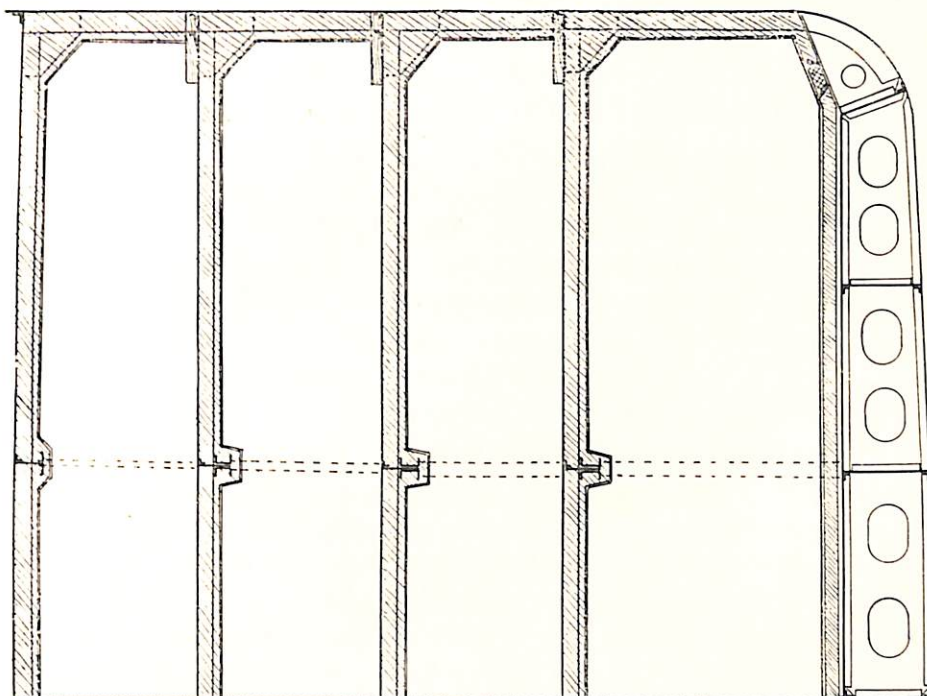
Refrigerated Ship.—In these ships, the system of construction is identical with that of the ordinary ship, except that the holds must be lined with insulating material. Their general arrangements are slightly different. Ships built for the chilled meat and banana trades usually have more 'tween-decks than normal, to meet the special requirements of their cargoes.

Self Trimming Ship.—To reduce the trimming of cargo to a minimum in certain types of ships, such as colliers, it is desirable to have large, clear holds and deep, wide hatchways. To maintain strength in such ships, the coamings are often made continuous and are strengthened, together with the deck. Pillars are often omitted and deep brackets fitted in lieu of them, between the ship's side and the coaming. If the hatchways are long, as is often the case, web frames may be fitted in the holds, together with heavy beams which extend across the hatchway.

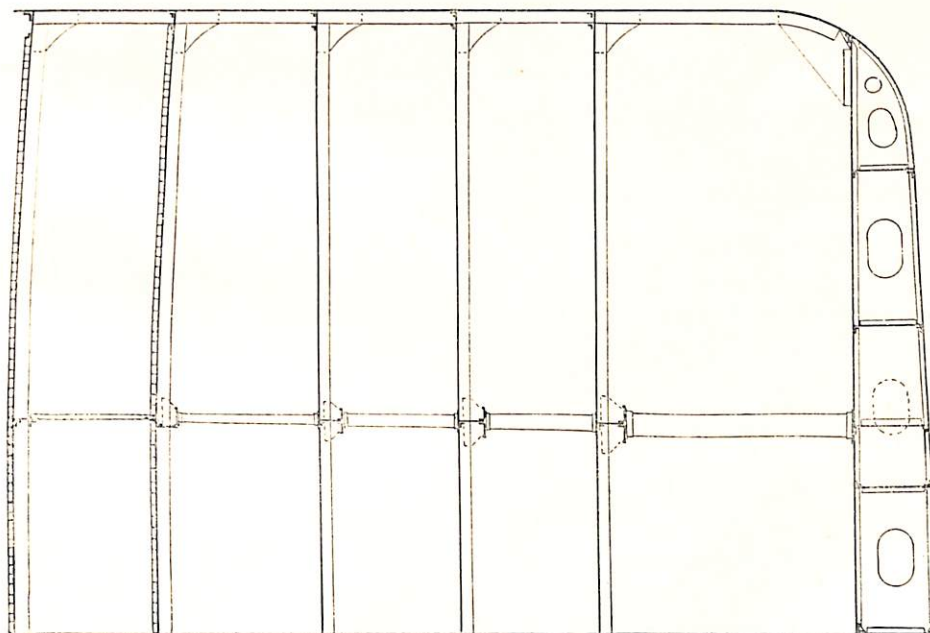
Isherwood System.—The ordinary Isherwood system is not shewn here, but a full description of it can be found in the section on oil tankers. It is a system of widely spaced, deep transverse frames, associated with longitudinal framing. This type is rarely used for ordinary ships, as the deep transverse framing causes too much broken stowage; but it is used almost exclusively for oil tankers.

Isherwood Combination System.—In order to overcome the disadvantages of the Isherwood system for ordinary ships, the Isherwood Combination system was introduced. In this, the longitudinals are retained in the bottom and under decks, but ordinary framing is used for the sides.

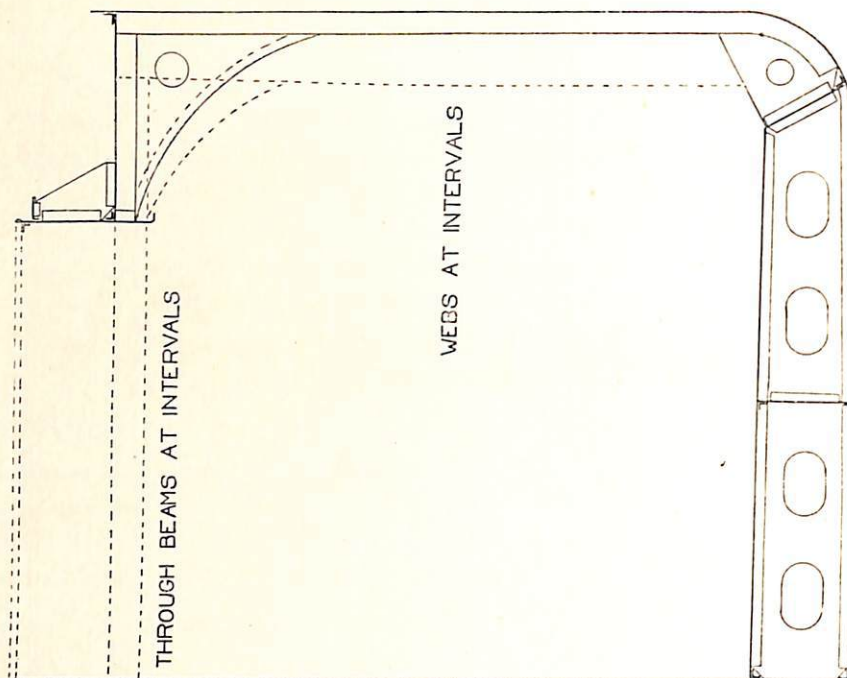
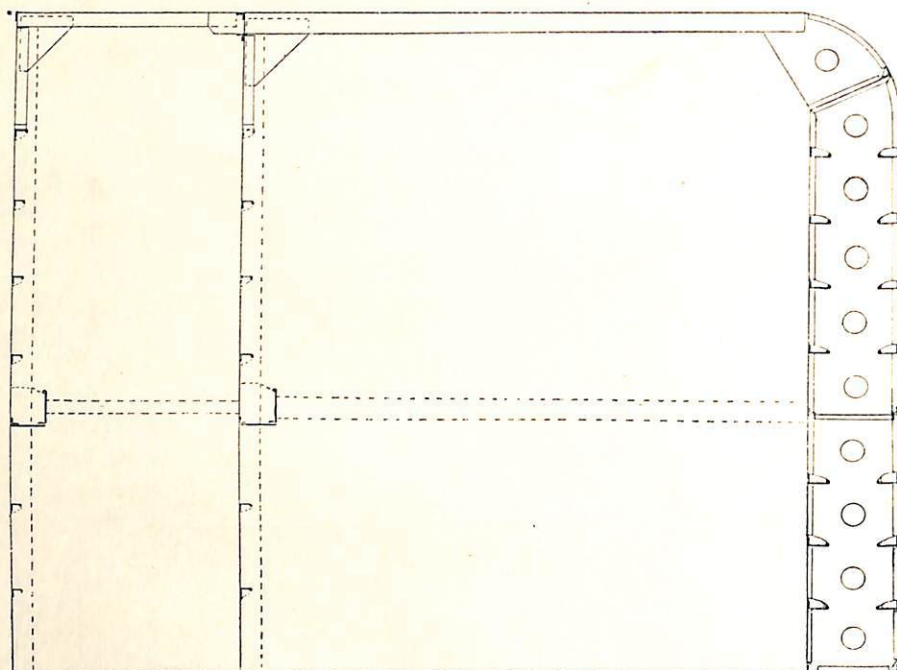
Beams and floors are widely spaced. At intermediate frame spaces, the beams extend to the first longitudinal only. At intermediate floor spaces, brackets extending to the first longitudinal frame are used.



REFRIGERATED SHIP.



PASSENGER SHIP.



STRESSES AND STRAINS IN SHIPS.

Stress and Strain.—Stress is load put on a piece of material or on a structure. If the stress is excessive, the material may become permanently deformed and weakened and it is then said to be “strained.”

Types of Stress.—Stresses are classified according to the way in which they act.

Tensile stresses try to pull the material apart.

Compressive stresses try to crush the material.

Shearing stresses may be described as the effect of forces which try to shear material across, or to make the component parts of a structure slide over each other.

Bending stresses are compound stresses produced by forces when they try to bend a piece of material.

Longitudinal Bending Stresses.—If a beam or girder is bent, as shewn in Figure 9, the greatest tensile and compressive stresses occur at the top and bottom. Somewhere between the two, there is a line called the “neutral axis” at which these stresses cease to exist. Shearing stresses are, however, least at the top and bottom and greatest near the neutral axis.

Stresses in Ships.—These may be divided into two classes, viz. :—

Structural—affecting the general structure and shape of the ship.

Local—affecting certain localities only.

A ship must be built strongly enough to resist these stresses, otherwise they may cause strains. It is, therefore, important that we should understand the principal ones and how they are caused and resisted.

Principal Structural Stresses.—Hogging and Sagging ; Racking ; effect of water pressure ; and drydocking.

Principal Local Stresses.—Panting ; Pounding ; effect of local weights ; and vibration.

Hogging and Sagging.—These are longitudinal bending stresses, which may occur when a ship is in a seaway, or which may be caused in loading her. Figure 2 shews how a ship may be hogged and Figure 3 how she may be sagged by the action of waves. When she is being loaded, too much weight in the ends may cause her to hog, or if too much weight is placed amidships, she may sag.

The dark lines in Figure 4 show how these stresses are resisted. At the bottom, all longitudinal work in the double bottom gives the necessary strength. At the top, the deck stringer and sheerstrake are thickened, so as to make a strong L-shaped girder on either side. The stresses are greatest amidships, so the strength of the parts mentioned is made greater amidships than at the ends.

STRESSES AND STRAINS IN SHIPS—(Continued).

In long ships, the shearing stresses which occur near the neutral axis also become an important problem. In ships of over 500 feet long, it is necessary to increase the riveting in seams of shell plating at about the half-depth of the ship, in the neighbourhood of one-quarter of the length from each end.

Racking.—Figure 5 shews how a ship may be "racked" by wave action, or by rolling in a seaway. The stress comes mainly on the corners of the ship, that is, on the tank side brackets and beam knees, which must be made strong enough to resist it. Transverse bulkheads provide very great resistance to this stress.

Effect of Water Pressure.—Water pressure tends to push-in the sides and bottom of the ship. It is resisted by bulkheads and by all transverse members (Fig. 6.).

Panting.—Panting is an in and out motion of the plating in the bows of a ship and is caused by unequal water pressure as the bow passes through successive waves. Fig. 7 illustrates how it is caused. It is greatest in fine bowed ships. For the means adopted to resist it, see "Peak Tanks."

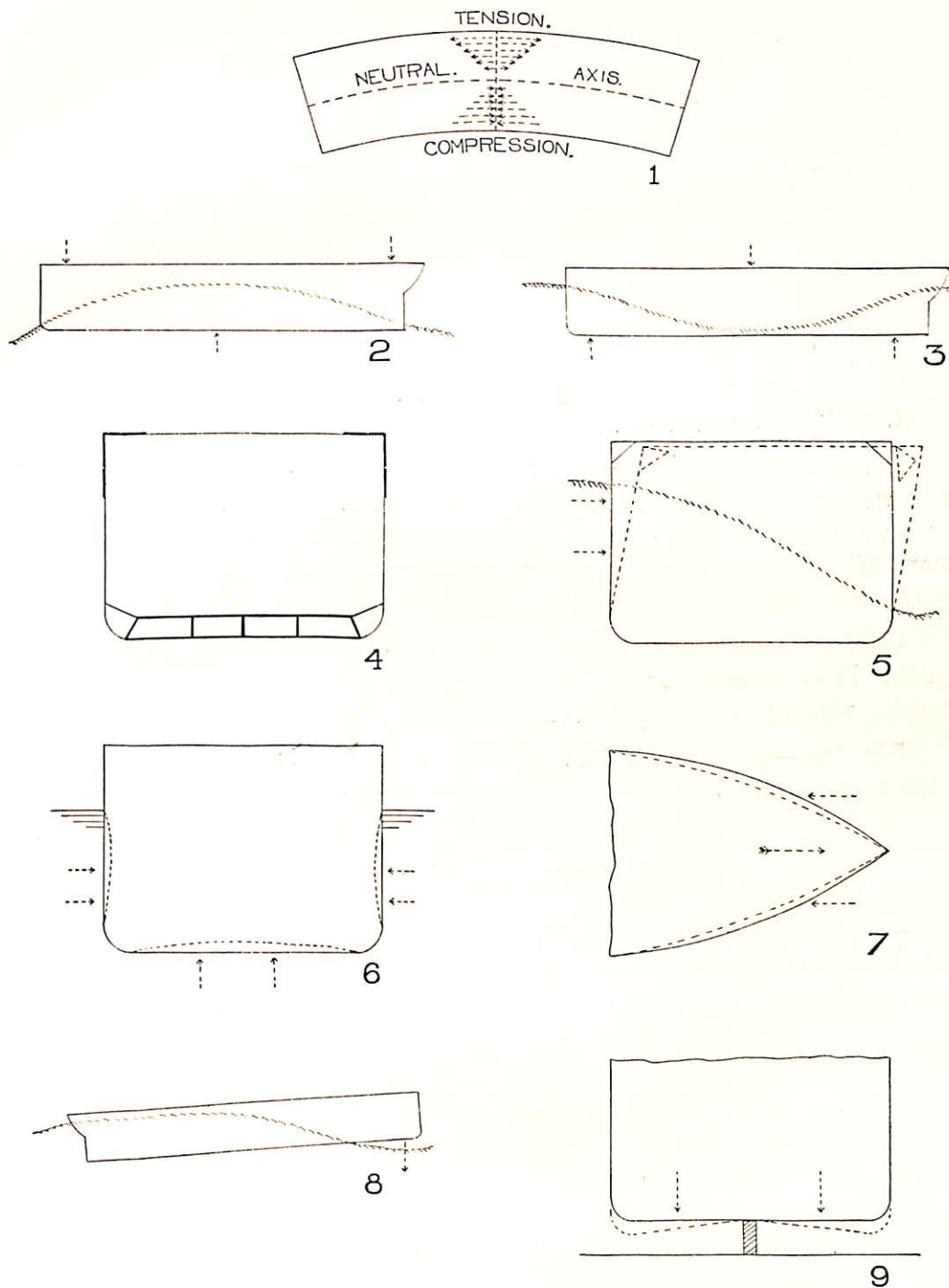
Pounding.—When a ship is pitching, her bows often lift clear of the water and then come down heavily, as shown in Fig. 8. This is known as "pounding" and occurs most in full-bowed ships. It causes damage to connections and riveting in the three strakes of plating next to the keel and in the general girder-work of the inner bottom just abaft the collision bulkhead. For the strengthening to resist pounding see "Cellular Double Bottoms."

Local Weights.—Local strengthening is introduced to resist stresses set up by local weights in a ship, such as engines. This is also done where cargoes imposing extraordinary local stresses are expected to be carried.

Drydocking.—It can be seen from Fig. 9 that a ship, when in drydock and supported by the keel blocks, will have a tendency to sag at the bilges. In modern ships of normal size, the cellular double bottom is strong enough to resist this stress without any further strengthening.

It is worth noting that if sagging does occur, it can always be remedied by the use of bilge blocks.

Vibration.—Vibration from engines, propellers, etc., tends to cause strains in the after part of the ship. It is resisted by special stiffening of the cellular double bottom under engine spaces and by local stiffening in the region of the stern and after peak.



STRAINS IN SHIPS.

BAR KEELS.

Lloyd's Dimension.—*L.*

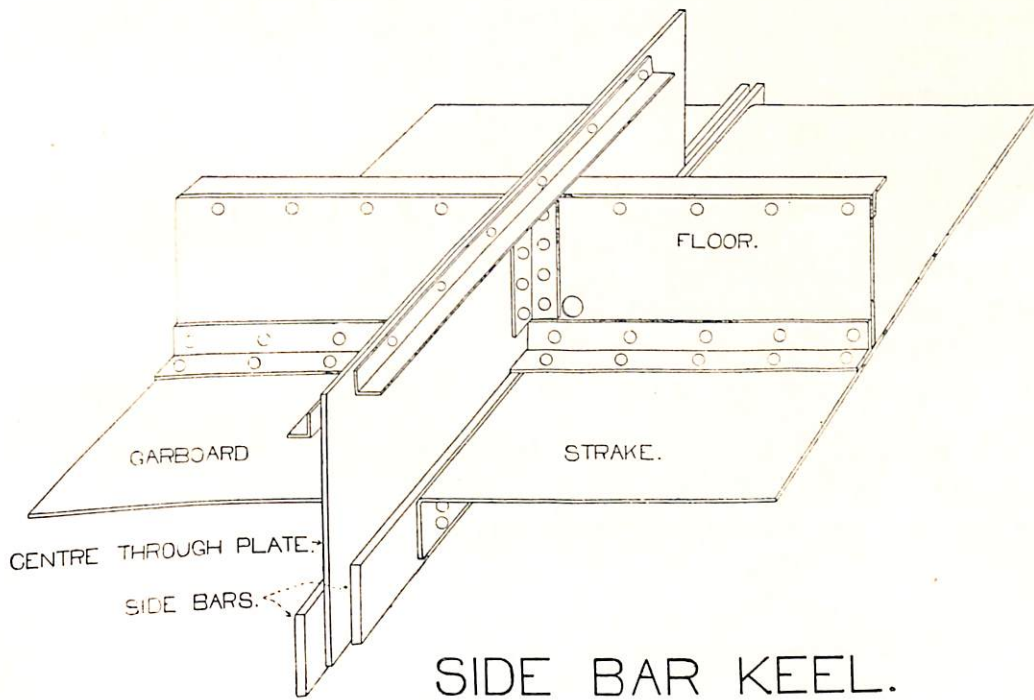
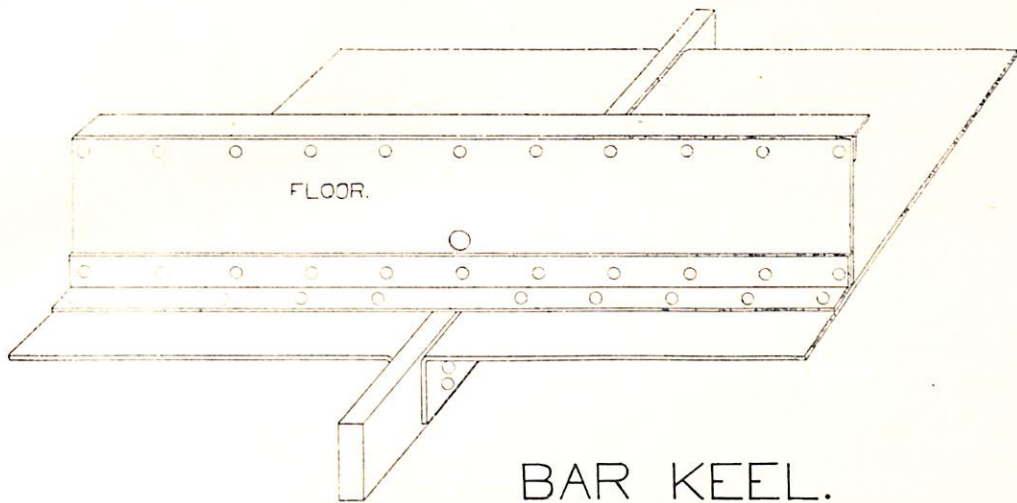
History.—Bar keels were the type first used when shipbuilding changed from wood to iron. It was found that they did not provide sufficient strength for large vessels, as there was no direct connection between the keel and the floors. They are now rarely used for any but small craft, having been replaced by the flat plate keel.

General Details.—The depth of the bar is from three to six times its width. It is made in lengths of from 30 feet to 60 feet, joined by vertical scarphs, which have a length of nine times the thickness of the keel.

Riveting.—Garboard strake to keel—double riveted, chain or zig-zag pitch of 5 diameters.

SIDE BAR KEELS.

Side Bar Keels were designed to overcome the lack of strength of the Bar Keel, but were expensive to construct and repair. They have been superseded by the flat plate keel and may be regarded as obsolete.



FLAT PLATE KEELS.

Lloyd's Dimensions.—*L and d.*

General.—The flat plate keel is the modern keel. It has the strength of the older types, without their disadvantages.

Keel Plate.—This may have a width of from 35 inches to 68 inches. It must be of full thickness for the three-fifths length amidships, but beyond this it may be reduced slightly towards the ends. The end joints are usually lapped; the laps being scarphed, or fitted with tapered liners to present a level surface for the attachment of the centre girder, etc.

Centre Girder.—This may be between 27 inches and 55 inches in depth and is made in lengths of from 24 feet to 28 feet, with lapped joints. It is connected to the keel and inner bottom by double angles in vessels of more than 350 feet length and attached to floors by single angles in all parts except machinery and boiler spaces.

Riveting.—The end laps of the keel plate and centre girder are triple or quadruple riveted in all but small vessels. They are to be chain riveted with a pitch of $3\frac{1}{2}$ or 4 diameters.

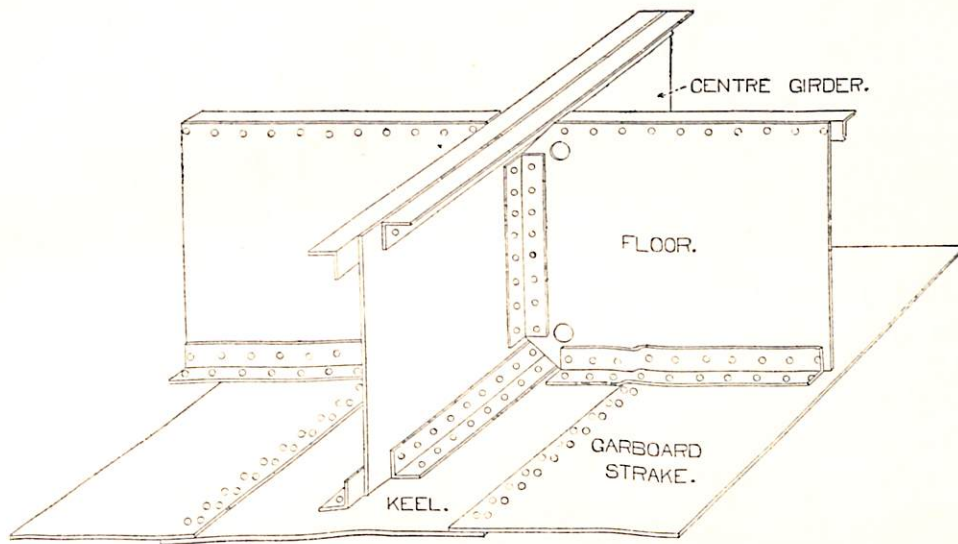
The end laps of the centre girder are riveted as for keel plates, save that the pitch of riveting need only be 4 diameters.

In ships of over 275 feet length, the garboard strake is double-riveted to the keel with a pitch of 4 diameters.

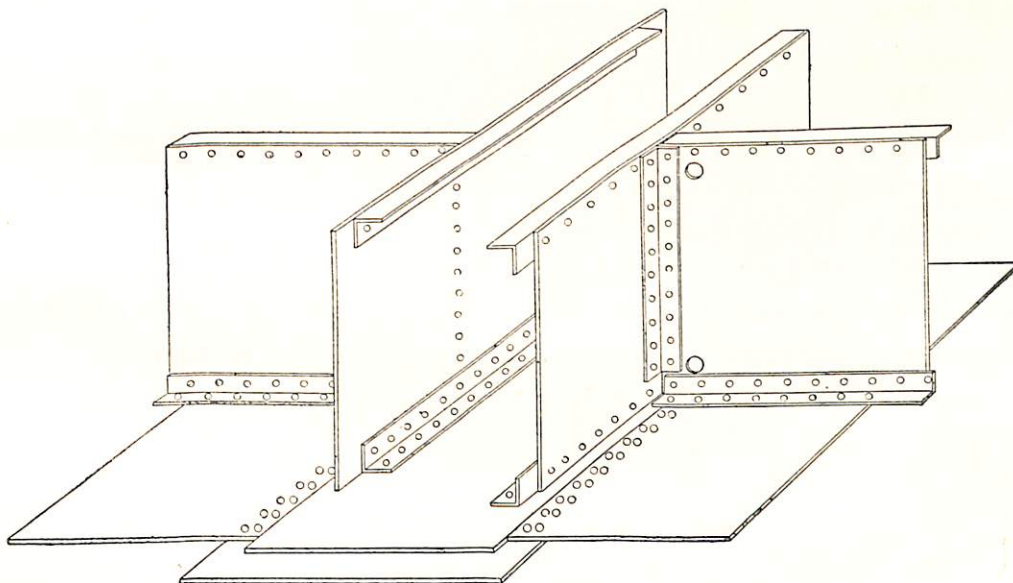
In the angles connecting the centre girder to keel, inner bottom to keel and floor to keel, the pitch of riveting is to be 5 diameters.

DUCT KEELS.

Duct keels are similar in construction to flat plate keels, save that they have two centre girders instead of one. They make a convenient tunnel for pipes to tanks, etc., to pass through.



FLAT PLATE KEEL.



DUCT KEEL.

OPEN FLOORS.

History.—Open floors were the original type for all ships and were originally associated with the frame and reverse and with the bar keel (See page 24). They have been largely superseded by cellular double bottoms, although they are still found in some types of small ship.

The modern open floor differs chiefly from the original type in that it usually has brackets at the bilge and is associated with the modern frame sections.

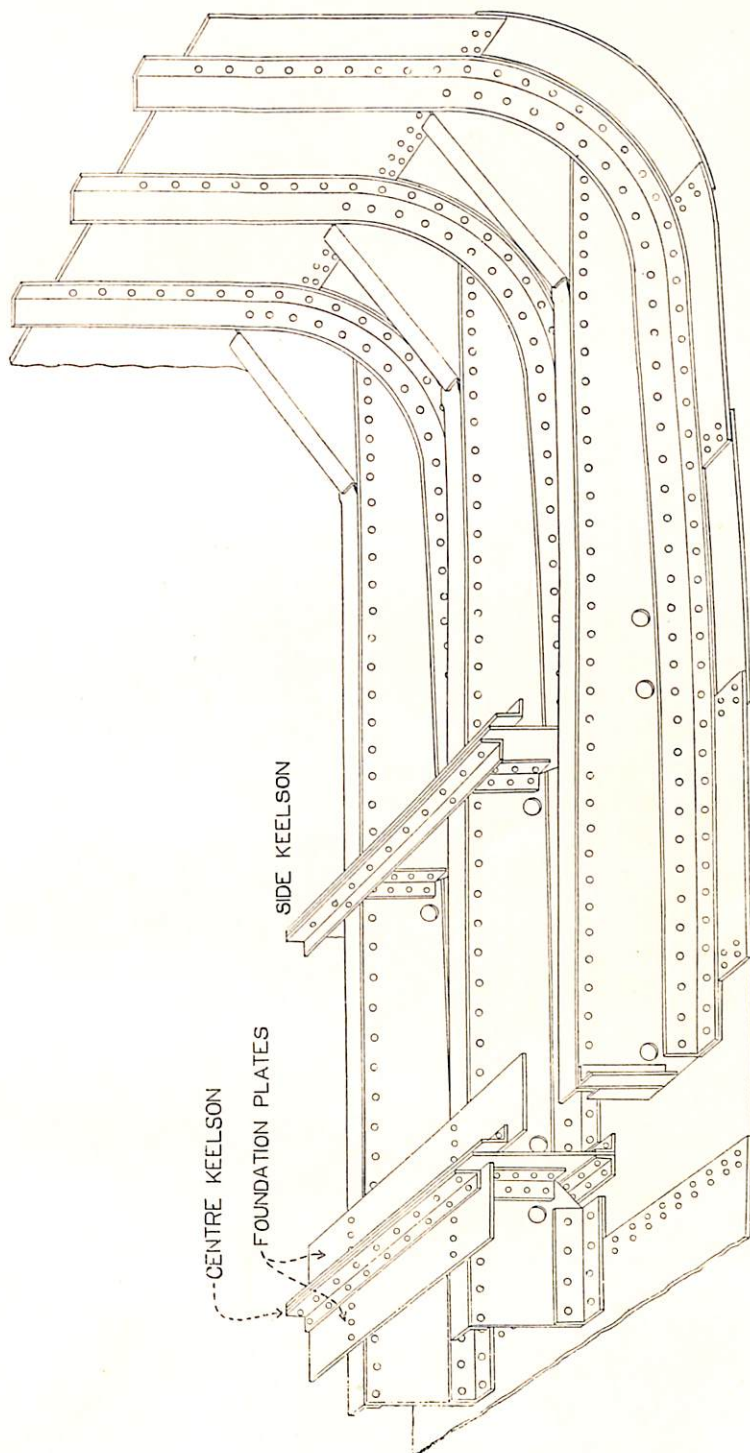
Floors.—Floors must be fitted at every frame and their tops must be level from side to side of the ship.

Brackets.—These must be of the same thickness as the floor and must be flanged. Their breadth and depth, clear of the frame and floor, must be equal to the depth of the floor at the centre line.

Keelsons.—These are longitudinal girders, running fore and aft to give strength in that direction. They were originally mere double angles, running along the tops of the floors. In modern ships which have open floors, intercostal plates are fitted in conjunction with these angles, to form “intercostal keelsons.”

If the breadth of the ship is 30 feet, or less, one side keelson is to be fitted on each side. If the breadth is between 30 feet and 54 feet, two side keelsons must be fitted on each side.

Riveting.—Frame to floor and shell: $5\frac{1}{2}$ diameters for the forward one-quarter of the ship's length: 6 to 7 diameters elsewhere. Reverse frame to floors: 7 diameters.



OPEN FLOORS.

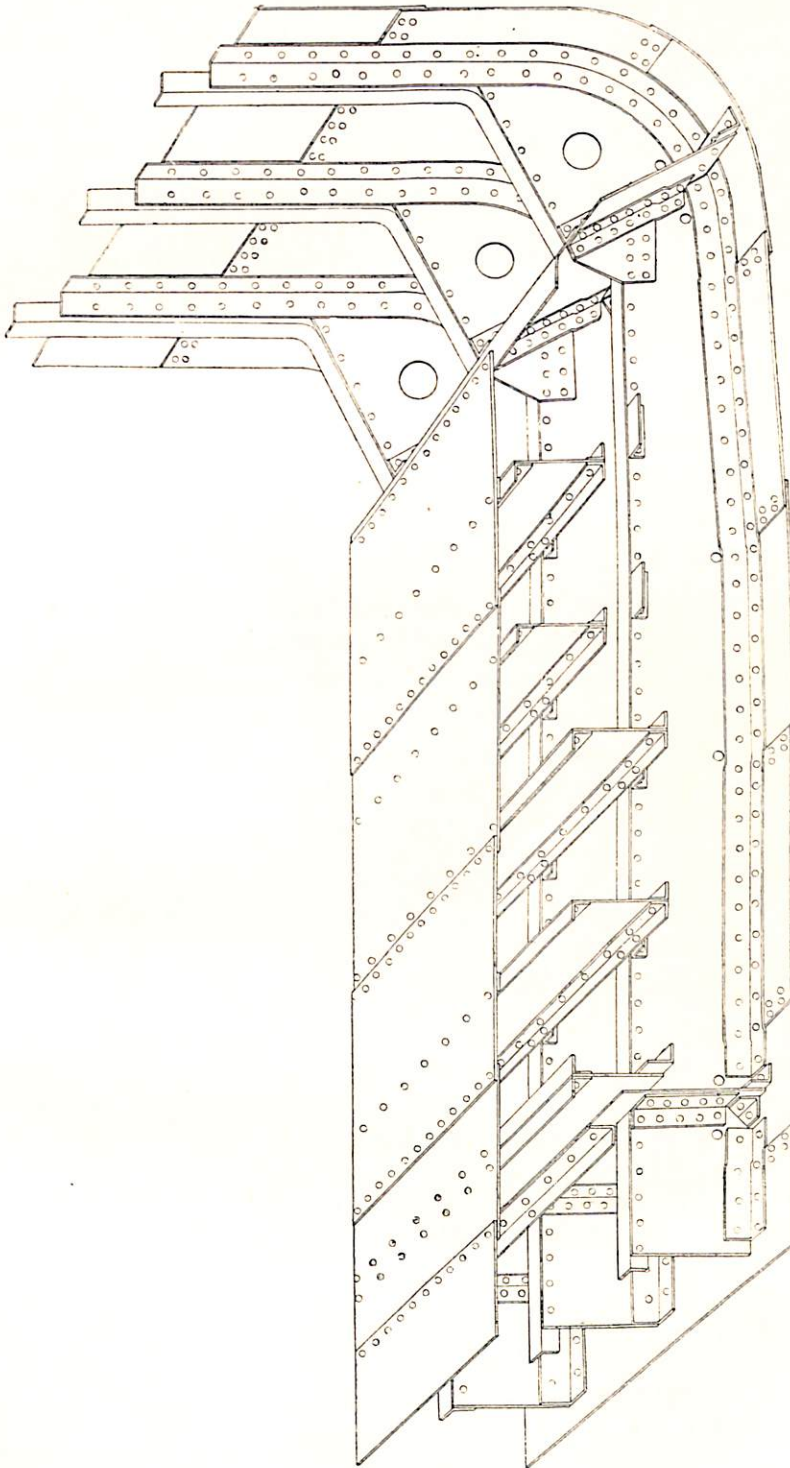
THE McINTYRE TANK.

History.—This tank was the forerunner of the cellular double bottom. Previous to its introduction, attempts had been made to plate-in the bottom of ordinary open-floored ships. In order to maintain water-tightness, collars were fitted around the frames, etc., at the bilge, but were not very satisfactory.

McIntyre solved this difficulty by cutting the frames at the bilge, fitting a continuous margin plate and angle and maintaining strength by means of brackets.

These tanks are still used in a few special types of ships, such as tankers, but otherwise have been replaced by the cellular double bottom.

Details.—Note the longitudinal girders running fore and aft along the top of the floors and the bracketing arrangements at the margin plate.



McINTYRE TANK.

CELLULAR DOUBLE BOTTOMS.

Lloyd's Dimensions.—*L and d.*

History.—Cellular double bottoms were developed from the McIntyre tank over which they have the advantages that :—

- (a) They carry the maximum of water ballast without encroaching on cargo space.
- (b) They are reasonably small and therefore easy to fill or empty.
- (c) They increase safety in the event of the bottom being holed, as they are fitted right through the ship from peak to peak.

Floors.—Floors may be of either the solid or the bracket type. The former are to be fitted at every space under the engine room, boilers, bulkheads and for the forward $\frac{1}{4}$ of the ship's length. Otherwise, they may be fitted not more than 10 feet apart, with bracket floors at the intermediate frame spaces.

Solid Floors.—These are sometimes called "Plate Floors." They are attached to the inner and outer bottoms by single angles (the "frame bar" and "reverse bar"), except under machinery and in the panting region. They are normally attached to the margin plate by single angles.

Watertight floors must be fitted under or near watertight bulkheads. These must be slightly thickened; whilst if the depth of the centre girder exceeds 36 inches, they must also be fitted with vertical stiffeners.

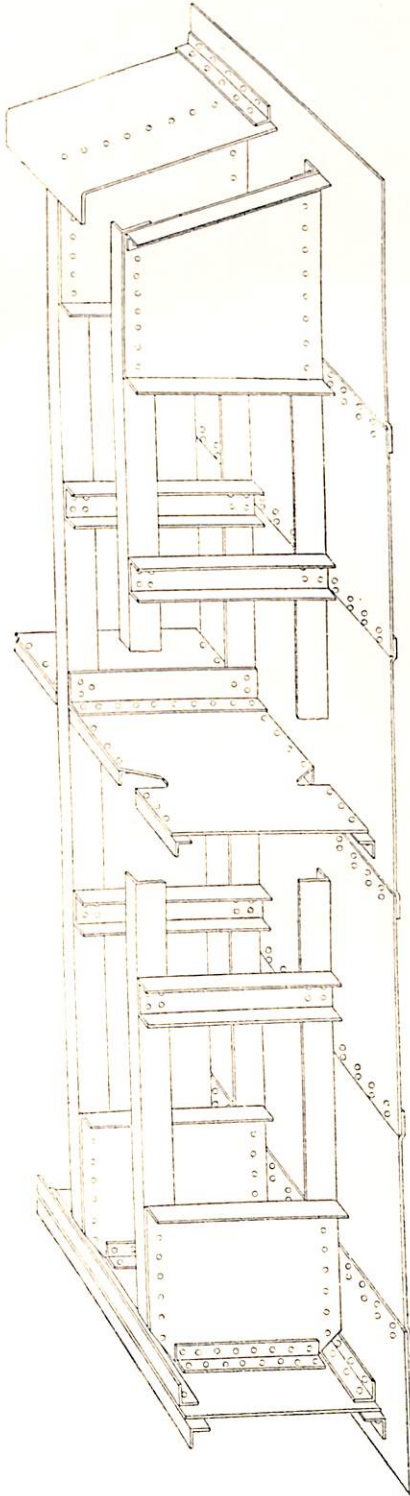
Bracket Floors.—The brackets are to have the same thickness as solid floors; to be flanged on their free edges; and their breadth is to be at least three-quarters of the depth of the centre girder. Where the intercostal side girders pass through bracket floors, vertical bars of the same size as the reverse bar must be fitted.

Lloyd's Rules quote a maximum unsupported span of 8 feet for bracket floors. If the distance from the side girders to the brackets exceeds this, vertical channel bars are fitted to reduce the span.

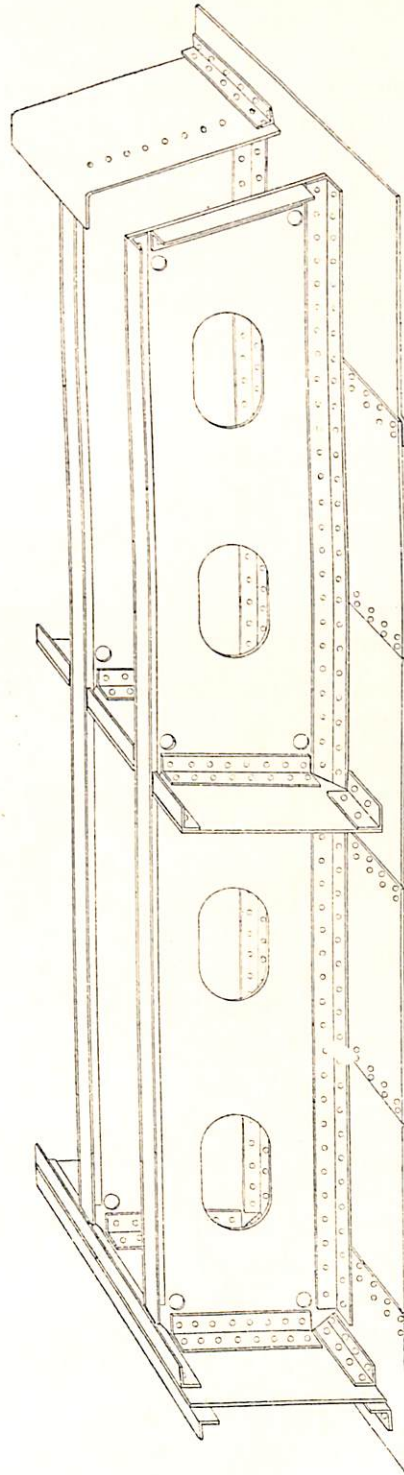
Centre Girder.—See "Flat Plate Keels."

Side Girders.—Vessels of 34 feet to 64 feet breadth are to have one side girder on each side: vessels of 64 feet to 80 feet breadth are to have two such girders on each side. These girders must extend as far forward and aft as possible.

Additional side girders must be fitted in the way of engine seatings and thrust blocks, and all such girders in these parts must have double angles on their upper edges.



BRACKET FLOORS.



SOLID FLOORS.

CELLULAR DOUBLE BOTTOMS—*(Continued).*

Inner Bottom Plating.—The middle line strake and margin plate must always be continuous fore and aft. Other strakes are sometimes laid athwartships under bulkheads, but should be fore and aft elsewhere. The thickness of the plating is increased slightly in the engine room and also under hatchways in which a ceiling is not fitted.

Riveting.—Rivet spacing in frame bars is $5\frac{1}{2}$ diameters in the forward $\frac{1}{4}$ of the ship's length, and 6 to 7 diameters abaft this.

Spacing in reverse bars is 7 diameters.

Side girders are connected to the shell and inner bottom by from 4 to 7 rivets between frames. The riveting connecting them to the floors has a pitch of 7 diameters.

In bracket floors, the brackets are attached to frame bars and reverse bars by from 4 to 9 rivets.

Floors are connected to margin plates by from 6 to 14 rivets, in the same way as the tank side brackets.

Seams and end laps of inner bottom plating usually have a rivet spacing of 4 diameters.

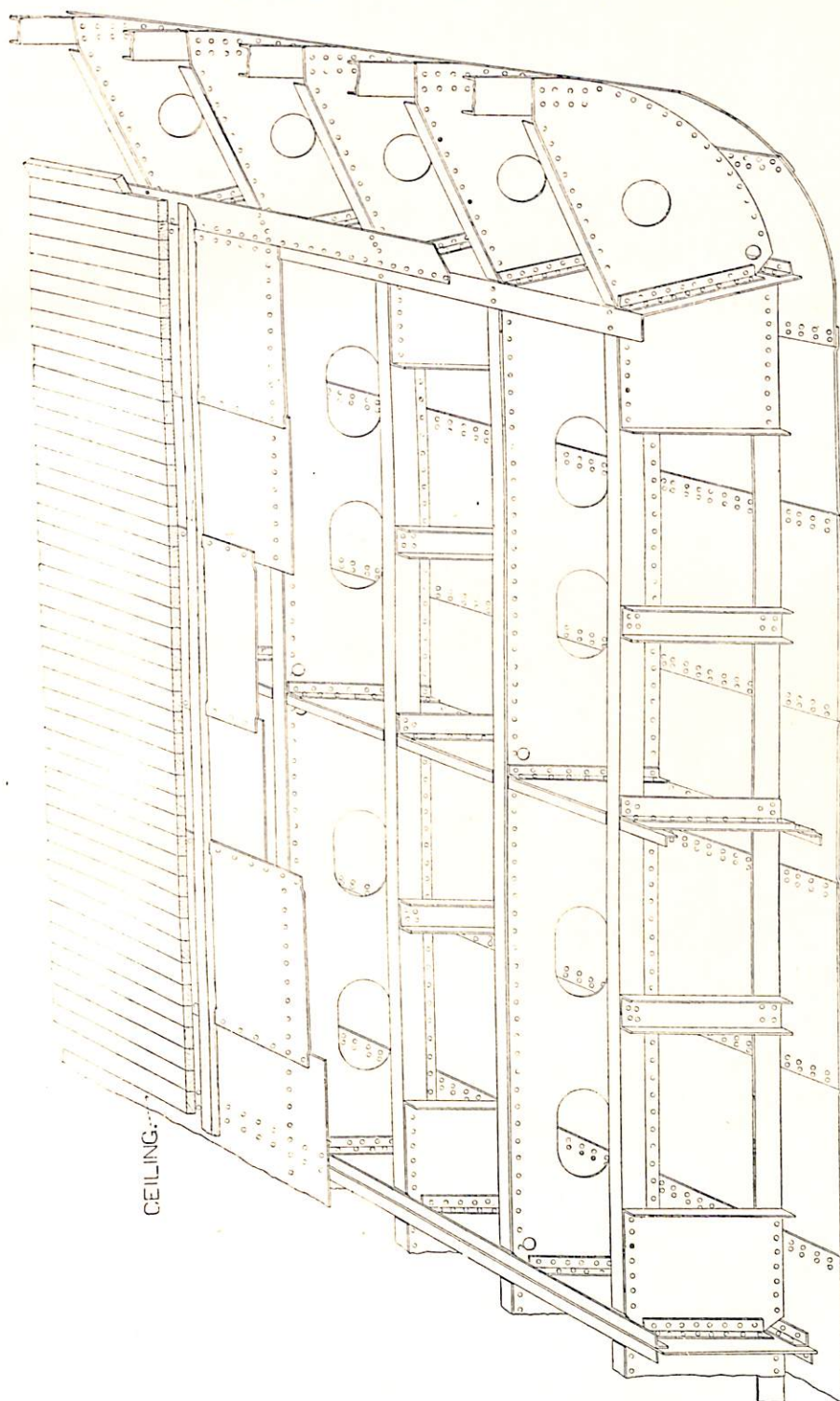
Precautions Against Pounding.—The bottom must be stiffened against pounding stresses throughout the forward $\frac{1}{4}$ of the ship's length, except for $\frac{1}{20}$ of the length right forward. This stiffening is as follows :—

The three strakes of plating next to the keel are thickened. Solid floors are fitted at every frame space and are connected to the outer bottom by double frame angles. Extra intercostal girders are introduced, 7 feet apart; also further intercostal girders of half the depth of the main ones, to support the plating between them. Riveting is decreased in pitch and the seams of shell plating are at least double riveted.

If longitudinal framing is used in the bottom, solid floors must be fitted at alternate frames, whilst the spacing of the longitudinals is decreased.

Double Bottoms for Oil Fuel.—If a ceiling is fitted in the hold, the scantlings and riveting may be the same as for any other double bottom. If no ceiling is fitted, the inner bottom plating must be double riveted. Holes must not be cut in the centre girder, although this need not be caulked or tested.

As a precaution against contamination of cargo through oil leakage, any ceiling which may be fitted must be laid on battens, so as to leave a half-inch air space between it and the tank top.



(FITTED FOR OIL FUEL).
CELLULAR DOUBLE BOTTOM.

CELLULAR DOUBLE BOTTOMS—(Continued).

Longitudinal Framing.—If longitudinal framing is used in the bottom the longitudinals must be bulb-angles, supported by solid floors not more than 12 feet apart. These floors are attached to the centre girder by double angles; and to the longitudinal by vertical angles which must extend for the full depth of the floor.

At intermediate frame spaces, between the floors, flanged brackets are fitted between the margin plate and the nearest longitudinal. The centre girder is supported by similar brackets, spaced not more than four feet apart. If the floors are more than 8 feet apart, vertical channel bars are fitted between them to support the longitudinals.

One intercostal side girder is fitted on each side if *B* exceeds 45 feet, or two on each side when *B* exceeds 70 feet.

The longitudinals are cut at watertight floors and attached to them by flanged brackets.

Tests.—Cellular double bottoms are tested by filling them to a head of water equal to the maximum head that could come on them in practice.

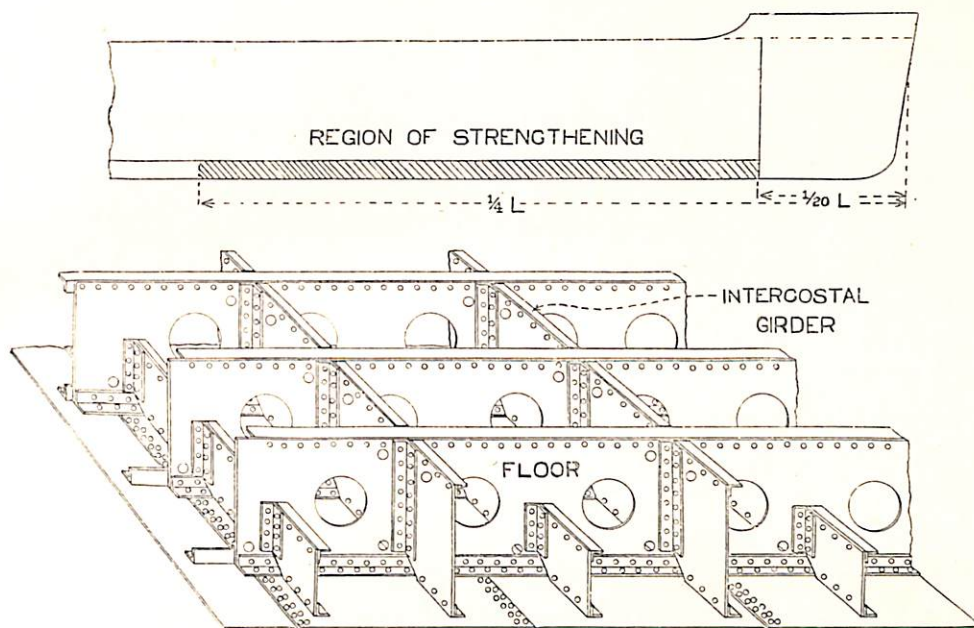
Passenger Ships.—The Ministry of Transport Rules require most passenger ships to be fitted with a double bottom, as follows:—

Ships of 200 to 249 feet long: from the machinery space to the collision bulkhead.

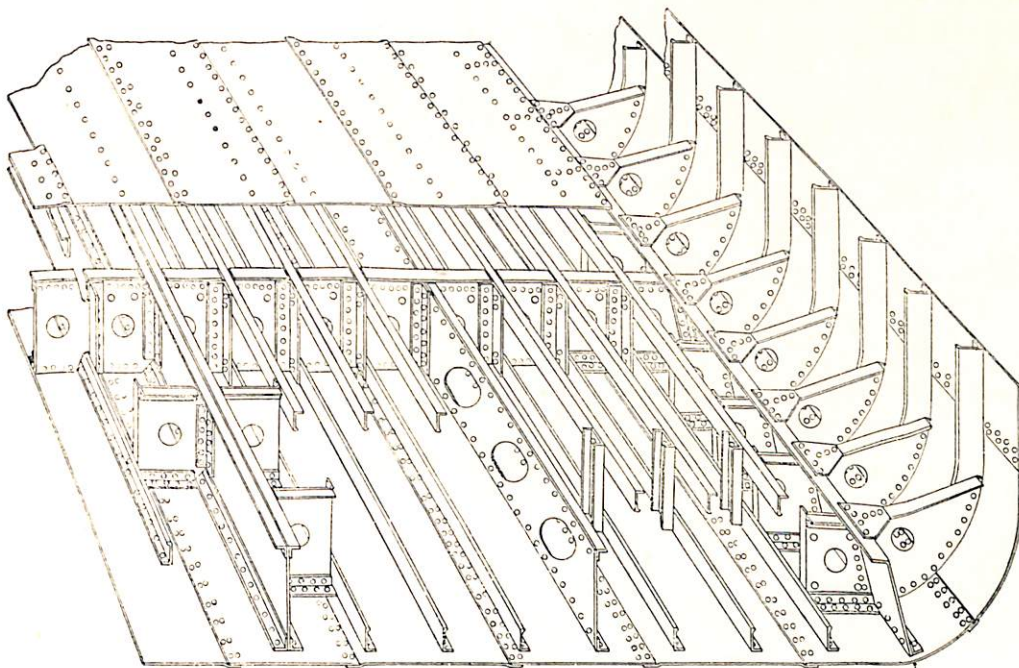
Ships of 249 to 330 feet long: from peak bulkhead to peak bulkhead, excluding the machinery spaces.

Ships of 330 feet long and over: from peak bulkhead to peak bulkhead, including the machinery spaces.

Provided that watertight compartments used exclusively for the carriage of liquids are exempt from the above requirements.



PRECAUTIONS AGAINST POUNDING.



LONGITUDINAL FRAMING.

MARGIN PLATES AND CONNECTIONS.

Lloyd's Dimensions.— L and d for margin plates.

D for tank side brackets.

Margin Plates.—The depth of the margin plate must be at least 80 per cent. or 85 per cent. of the depth of the centre girder. The flange on its upper edge must be wide enough to take separate connections to the gusset and the inner bottom plating.

Tank Side Brackets.—Tank side brackets must extend up the ship's side to a specified height above the base line. Their upper edges are stiffened by flanges or angles. They are normally connected to the margin plate by single angles.

Gussets.—The fitting of gussets is governed by a number of factors. In general, it may be said that they are fitted at every frame space, or a continuous plate fitted in lieu of them, in ships of medium or large size. In smaller ships they are fitted at every third frame space, but may be omitted altogether in very small ships.

Riveting.—The end laps of the margin plate are double to quadruple riveted, with a pitch of 4 diameters.

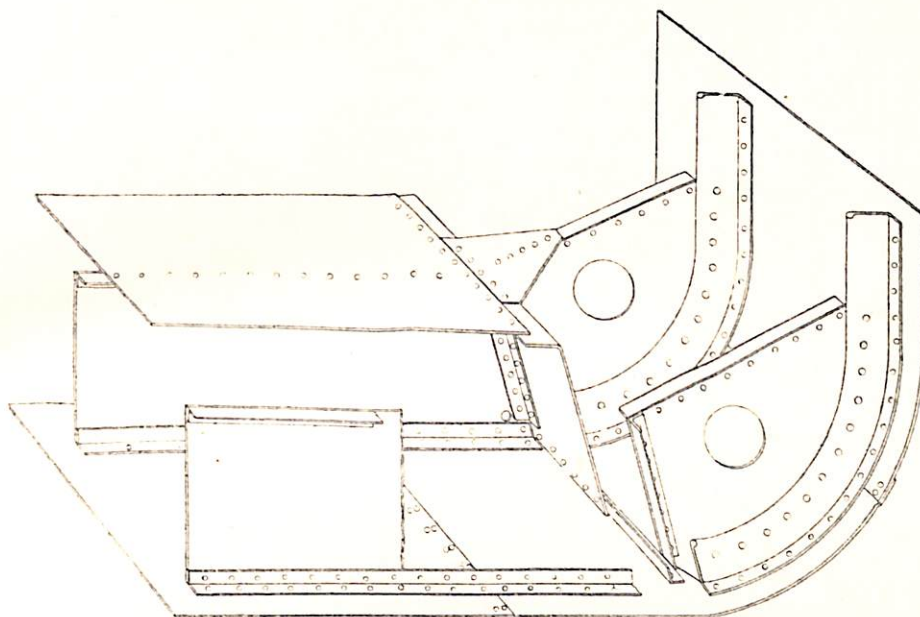
Riveting in the margin angle has a pitch of $4\frac{1}{2}$ diameters.

Tank side brackets are connected to the margin plate by from 6 to 14 rivets.

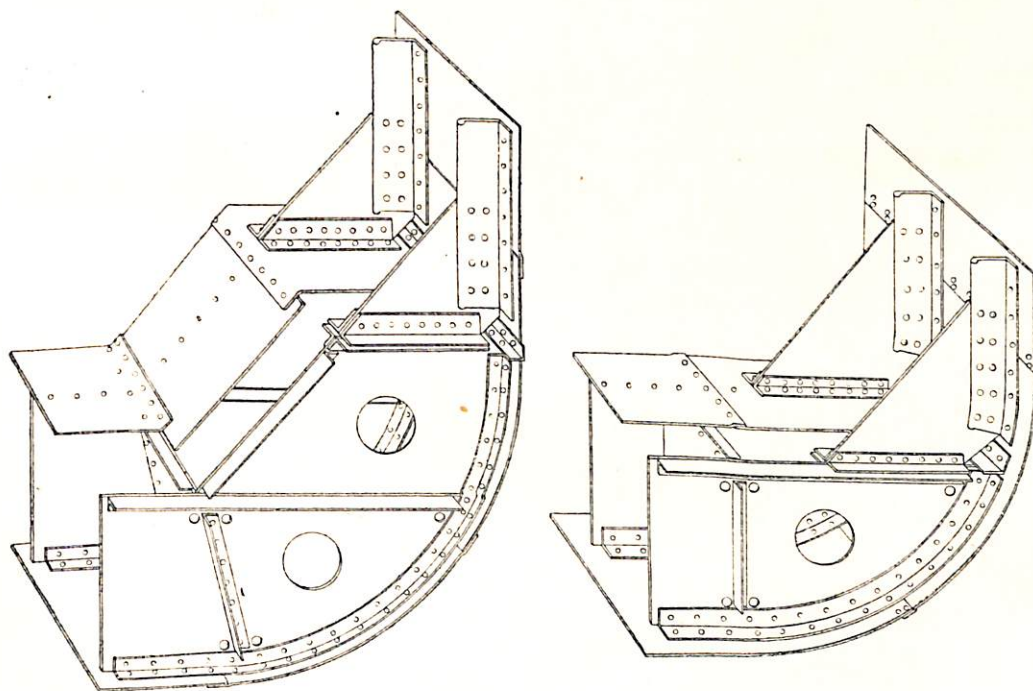
There must be from 5 to 15 rivets connecting the tank side bracket to the frame and the spacing of these rivets must not exceed 7 diameters.

Passenger Steamers.—The Ministry of Transport Rules now require that the inner bottom of a passenger ship must protect the bottom as far as the turn of the bilge. The outer edge of the margin plate must not be lower than a horizontal plane through the point where the line of the frames amidships is intersected by a transverse line, drawn at an angle of 25 degrees to the base line and cutting the latter at a point one-half of the ship's moulded breadth from the middle line.

The two lower sketches, opposite shew common methods of fitting margin plates in passenger ships.



ORDINARY SHIP.



MARGIN PLATES.

FRAMES.

Lloyd's Dimensions.— D , d and h .

Angles.—Angles are used in small ships only.

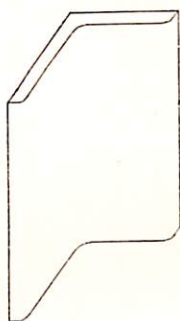
Frame and Reverse.—For ships in which angle frames alone were not strong enough, the angle was stiffened by riveting a reverse angle to its inner flange. With this system it was considered necessary to fit one or more side stringers to stiffen the structure, whilst further stiffening was sometimes provided by fitting web frames at intervals. After the bulb-angle and channel bar were introduced, the frame and reverse gradually disappeared and may now be regarded as obsolete.

Bulb Angles.—These are stronger and more rigid than the frame and reverse, suffer less from corrosion and save riveting. They also lend themselves easily to joggling (See "Shell Plating").

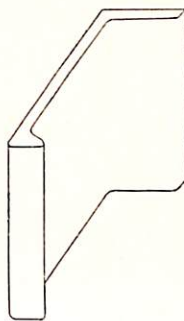
Channels.—These have the same advantage as the bulb angle and are very strong. They have the disadvantage that they are difficult to bevel at the turn of the bilge, but this can be overcome by cutting them short and using an angle to connect the tank side bracket to the shell plating.

Z-Bars.—These are efficient, but expensive to fit. Consequently, they are rarely used in merchant ships.

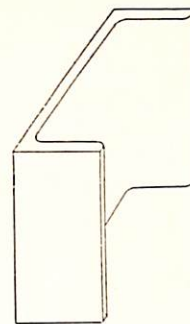
Web Frames.—As a general system for ordinary ships, the web frame, together with side stringers, disappeared at about the same time as the frame and reverse. They are still fitted in some parts of modern ships, such as engine rooms, where special local strength is required. They are usually associated with deep stringers.



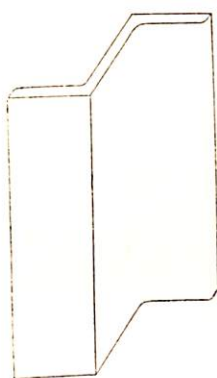
ANGLE



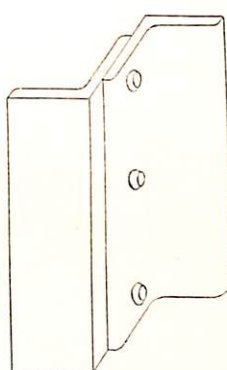
BULB ANGLE.



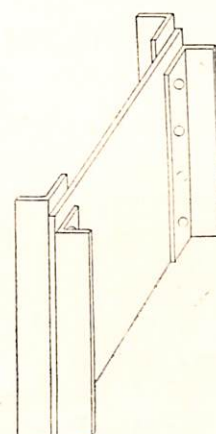
CHANNEL.



ZED.

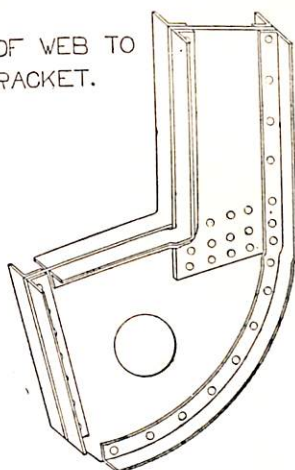


FRAME AND REVERSE

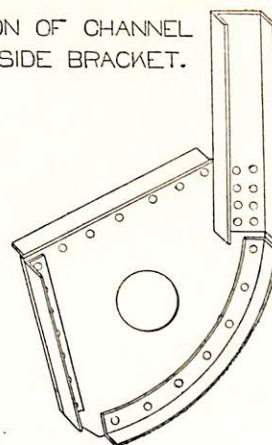


WEB.

CONNECTION OF WEB TO
TANK SIDE BRACKET.



CONNECTION OF CHANNEL
TO TANK SIDE BRACKET.



FRAMES.

FRAMES (*Continued*).

Frame Spacing.—For the main body of the ship, the frame spacing is between 21 inches and 38 inches. Between the collision bulkhead and a point one-fifth of the ship's length abaft the stem, it must not exceed 27 inches. In peak tanks and cruiser sterns, it must not exceed 24 inches.

Framing in 'Tween Decks.—In 'tween decks, the framing may, as a general rule, consist of lighter frames, scarphed on to the main frames. Alternatively, the main framing may extend to the upper deck at alternate frame spaces, with very light frames, scarphed on to the main frames intermediate frame spaces.

Framing of Superstructures.—In detached superstructures and certain types of upper 'tween decks, when the frame spacing does not exceed 30 inches, the frames may be fitted at alternate frames and the intermediate ones omitted. At each end of a bridge, however, four consecutive frames must extend right through to the bridge deck.

Riveting.—The pitch of rivets in frames must not exceed 7 diameters when the frame spacing is 29 inches or less : $6\frac{1}{2}$ diameters with frame spacing of between 29 and 32 inches : 6 diameters with frame spacing of between 32 and 34 inches : $5\frac{1}{2}$ diameters when the frame spacing exceeds 34 inches and also in the panting region.

Numbering.—Frames are usually numbered from aft to forward.

BEAMS.

Functions.—Beams have two main functions : to tie the sides of the ship together and to support the deck against water pressure and the weight of cargo.

Sections.—Angles, bulb-angles and channels are in general use. T-bulbs and other T-sections are largely used under wood decks. H-sections, and a variety of built sections are used as strong beams in engine spaces, etc.

Size.—The size of transverse beams is governed by the breadth, *B*, and their unsupported span.

Fitting.—Beams must be fitted at every frame space. If the frames are only fitted at alternate frame spaces, those beams which are placed between frames must have their knees attached to the shell plating.

Camber.—The standard camber is $1/50$, that is a rise of approximately $\frac{1}{4}$ inch for each foot of length of the beam. It does not give any strength to the deck, but merely helps to shed water.

Deck Longitudinals.—Longitudinal framing is sometimes fitted under decks, in lieu of beams. These are supported at intervals of not more than 12 feet by heavy transverse beams, and their size and spacing are governed by the ship's length, *L*, and their unsupported span. At bulkheads, they are cut and attached to the bulkhead stiffeners by brackets, similar to beam knees.

Strong Beams.—These are often fitted in engine and boiler rooms, to support deck longitudinals and sometimes as hatch-end beams. In other words, a strong beam is a specially heavy beam which is fitted where specially great local strength is required.

BEAMS—(Continued).

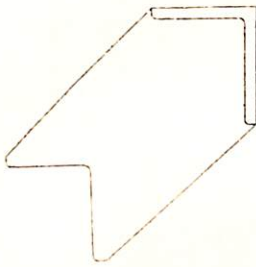
Half-Beams at Hatchways.—The beams which are cut at hatch side coamings are termed "half-beams." They are connected to the coaming plate, by single angles, except when the coaming forms part of a deck girder (See "Deck Girders").

Hatch End Beams.—Hatch end beams are usually riveted directly to the end coaming plate and are normally made stronger than other beams. For further details, see "Hatch Coamings."

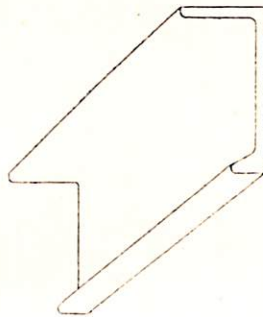
Cargoes Suspended from Beams.—When cargo is suspended from beams as in the case of chilled beef, the strength of the beams must be increased by between 30 per cent. and 150 per cent., according to circumstances.

Riveting.—The pitch of the riveting connecting beams to the deck is 7 diameters.

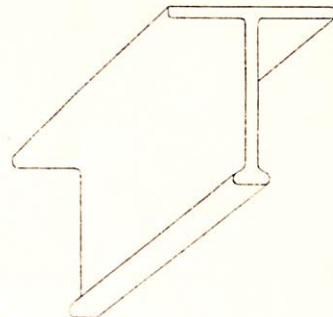
The angles connecting half-beams to hatch coamings must have 2 rivets in each flange if the depth of the beam does not exceed 8 inches. For deeper beams, there must be 3 rivets in each flange.



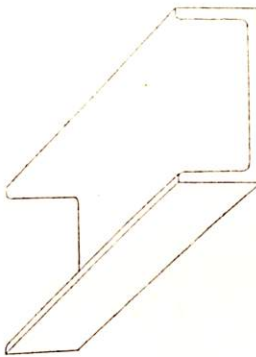
ANGLE.



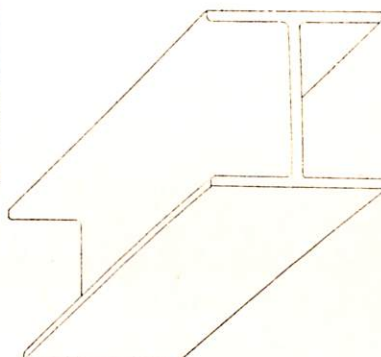
BULB ANGLE



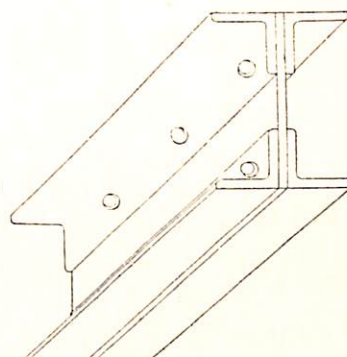
T-BULB.



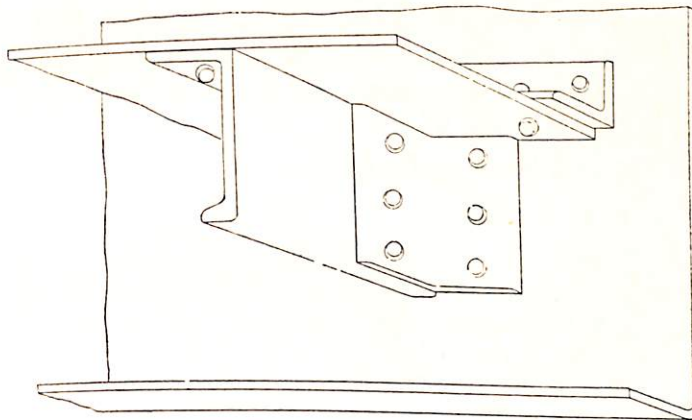
CHANNEL.



H.



BUILT H.



CONNECTION OF HALF-BEAMS TO HATCH COAMING.

BEAMS.

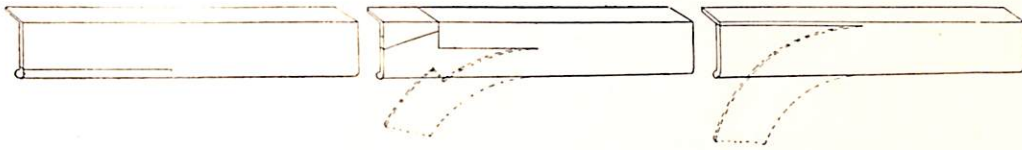
BEAM KNEES.

Plate Bracket Knees.—These are the strongest type and are almost exclusively used in large vessels. The depth of the knee and its overlap on the beam depends on the depth of the beam or frame, whichever is the greatest. If the knee is more than 36 inches deep, it must be flanged on its inner edge. The breadth of this flange must be between 2 inches and 3 inches, according to the depth of the knee.

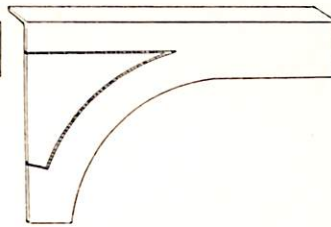
Fitting.—Frames and beams need not overlap, as the knee is considered to be a sufficient connection between them.

Riveting.—The knees must have from 4 to 10 rivets in each arm, according to their depth. Note that there is always the same number of rivets in the beam as in the frame.

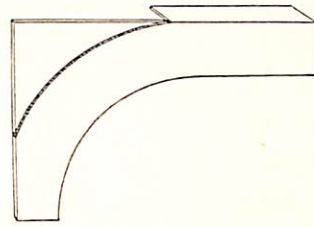
Other Types.—The other types shewn in the sketches are obsolete for large ships, but are still sometimes used in yachts, etc., where appearance is important. Note, in the sketches, how the beam is cut and the plate welded in.



SLABBED KNEE.



SPLIT KNEE.



TURNED KNEE.

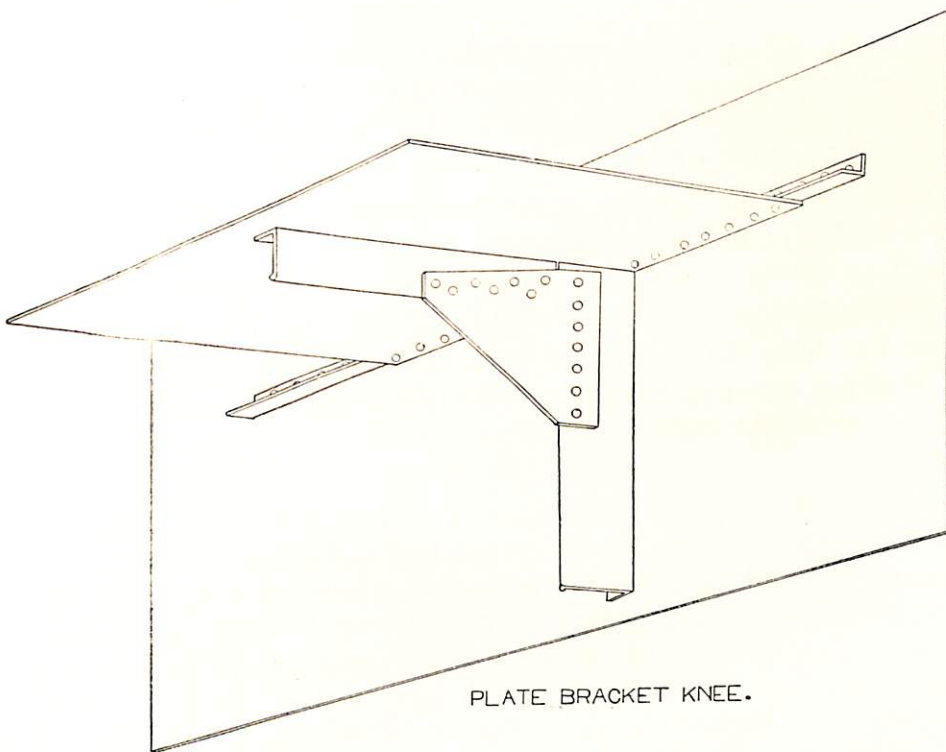


PLATE BRACKET KNEE.

BEAM KNEES.

STEEL DECKS.

Lloyd's Dimensions.—*L*, *B*, *D* and *d*.

Fitting.—Clinker plating is best, as water does not lodge in the seams, but it is rather expensive. Consequently, in and out plating, or joggled plating, is often used. As an alternative, the beams are sometimes joggled in such a way that the plating may be laid on them clinker fashion.

Thickness.—The thickness of the plating varies with locality. It is thicker amidships than at the ends and is thinner within the line of hatchways. Lower deck plating is usually thinner than that of strength decks.

Deck Stringers.—At strength decks, these are much thicker than the other strakes of deck plating, but not at lower decks. Their width is usually reduced towards the ends of the ship.

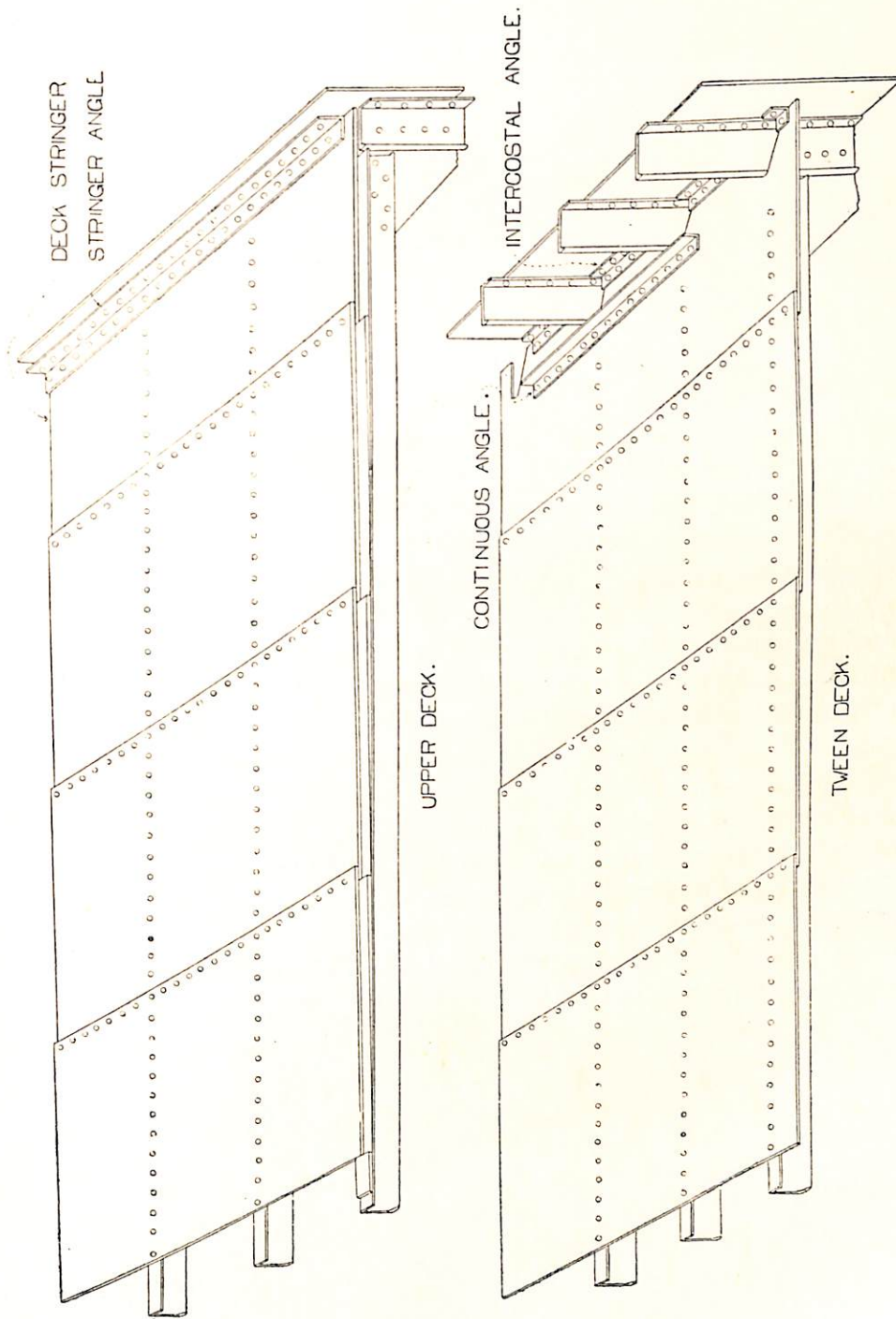
Deck Stringer Angles.—At upper decks, the size and riveting of the deck stringer angle depends on the thickness of the sheerstrake and deck stringer. Its width may be between 3×3 inches and 8×8 inches. At lower decks, it is intercostal between the frames.

Watertightness at Sides of Lower Decks.—The lower deck stringer is usually slotted to allow the frames to pass through it. The deck may be made watertight by fitting a continuous inner angle, which takes cement chocks, as shewn in the sketch; or by plates and angles, welded around the frames.

Deck Openings.—Strength must be maintained at the corners of hatchways and similar openings, by fitting doubling plates, or some similar arrangement. It may also be necessary to fit intercostal girders under the strength deck.

Riveting.—Seams of deck plating are single riveted, except with comparatively thick plating. End laps of deck stringers and strength deck plating may be double to quintuple riveted, according to thickness. End laps of lower deck plating may be single to treble riveted, according to thickness. The rivets in these seams and end laps all have a pitch of approximately 4 diameters.

Upper deck stringer angles are single riveted with a pitch of $4\frac{1}{2}$ diameters, unless they are more than .64 inch thick, when they are double riveted, with a pitch of 5 to 6 diameters; this would amount to double riveting in ships if over about 450 feet long. Lower deck stringers are single riveted.



STEEL DECKS.

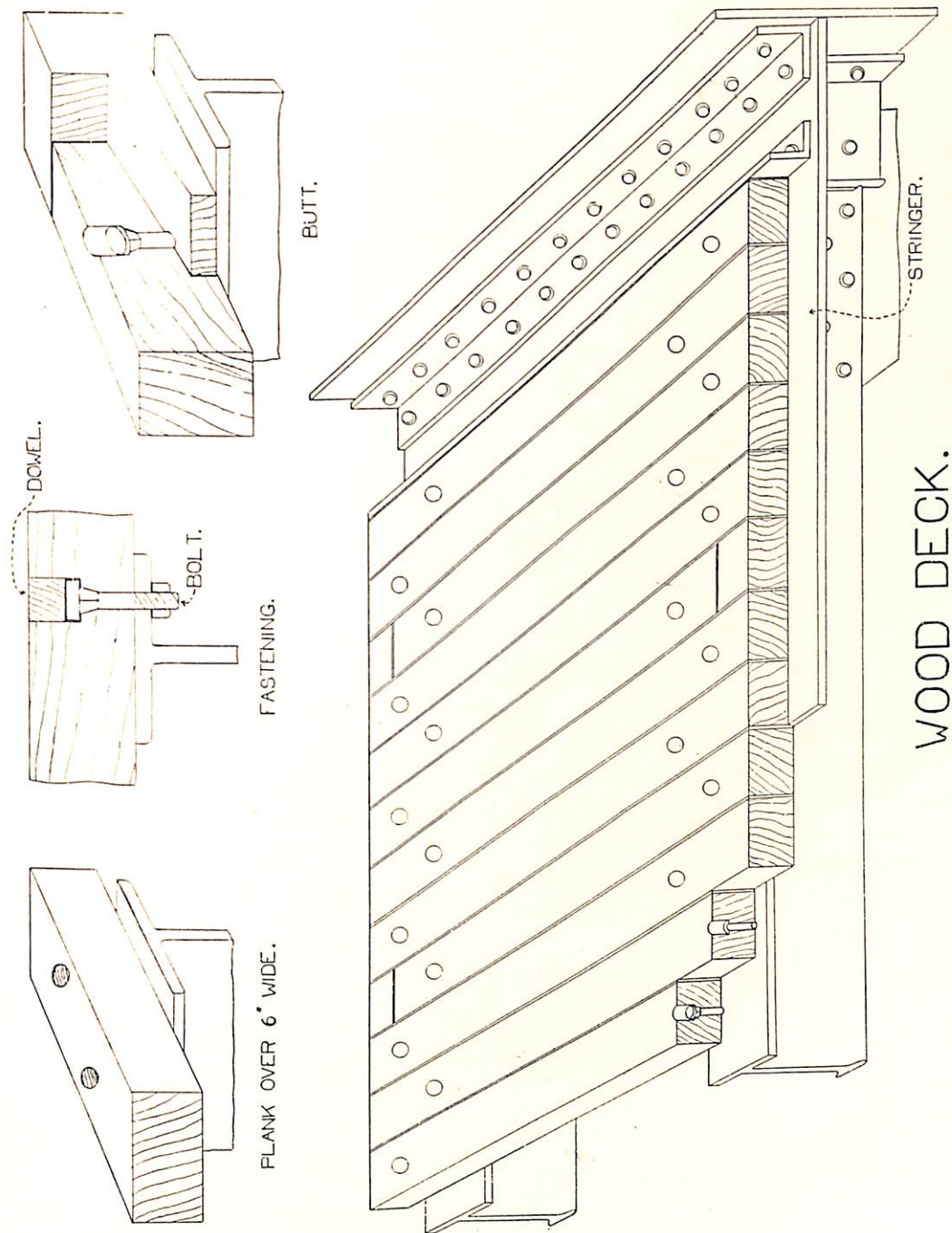
WOOD DECKS.

Wood Decks.—These are sometimes found in small passenger ships and are also used at times for light decks, such as boat decks and flying bridges, in larger vessels. They are not generally used for important decks of large vessels, as they lack strength and are difficult to keep watertight.

Planking.—Pine planking must be at least $2\frac{1}{2}$ inches thick and teak planking 2 inches thick.

Fastenings.—Each plank is fastened at every beam by galvanised bolts, which must have a diameter of at least $\frac{1}{2}$ inch. The heads of the bolts must be properly sunk, with oakum and white lead under their heads. Turned dowels are fitted in the holes and are bedded in marine glue, or some similar substance.

Strengthening.—If wooden strength decks, or lower decks, are fitted, they must be strengthened by steel deck stringers and tie plates, fitted on top of the beams and under the wood deck. Continuous tie plates must be fitted fore and aft on either side of the hatchways and similar openings, whilst transverse cross-tie plates are required at the ends of these openings. Abreast of machinery spaces, the decks must be completely plated over.



SHEATHED DECKS.

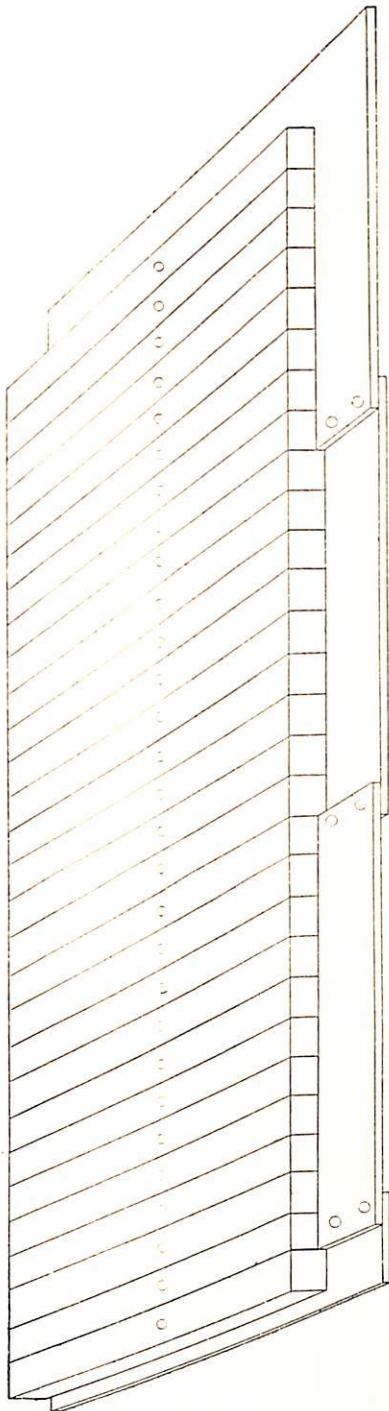
Sheathed Decks.—In passenger ships and in certain parts of other ships, a bare steel deck is undesirable, but the ordinary wood deck lacks strength and is difficult to keep watertight. This difficulty is often met by fitting a sheathed deck : that is, a steel deck, with a wood sheathing laid on it.

Steel Plating.—This is usually raised and sunken, and not clinker, for three reasons :—

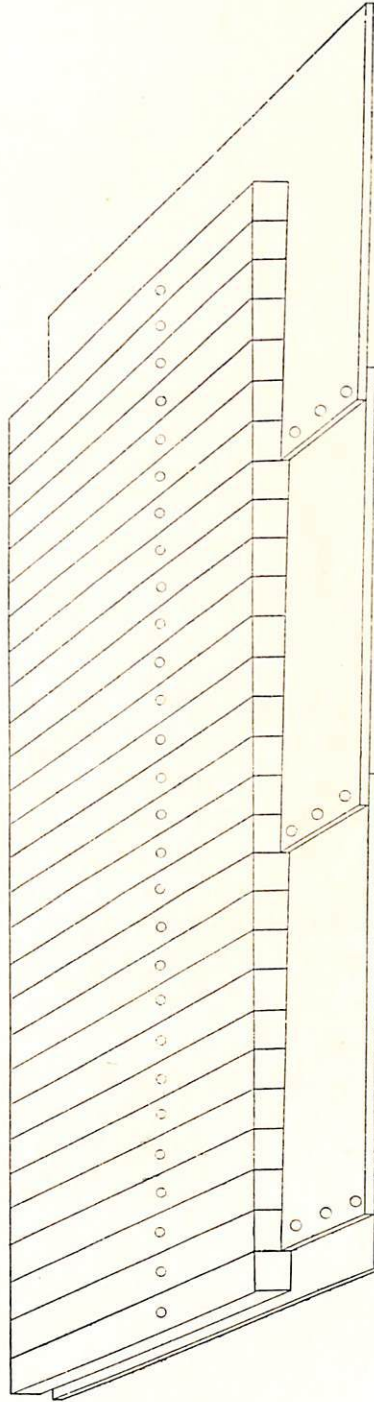
- (a) The steel deck is not required to shed water.
- (b) Raised and sunken plating is cheaper to fit than clinker plates.
- (c) It is easier to fit the wood deck over raised and sunken plating.

The steel deck need not be caulked, as long as the wood deck is properly caulked. Before the wood deck is laid, the steel is usually coated with bitumastic, or some similar protective coating.

Wood Sheathing.—The thickness of the wood sheathing may be $2\frac{1}{2}$ inches for pine, or 2 inches for teak. It is fastened to the steel deck by galvanised bolts, of not less than $\frac{1}{2}$ inch diameter, or by studs, welded to the steel deck. Athwartships planks are laid at the ends of hatchways, deck houses, etc.



IN AND OUT PLATING - GOOD PRACTICE.



CLINKER PLATING - DIFFICULTY OF FITTING.

SHEATHED DECKS.

RAISED QUARTER DECKS.

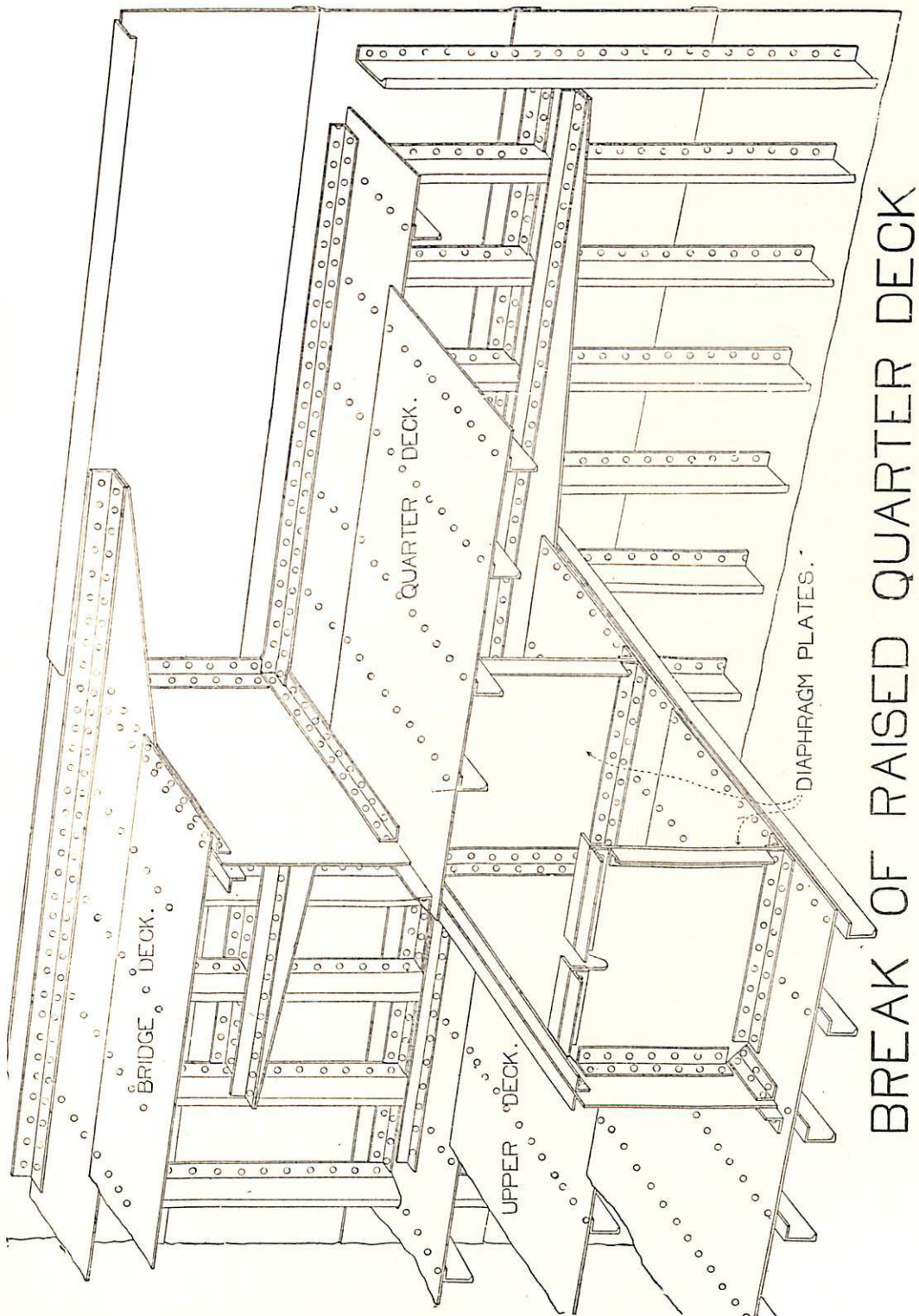
Lloyd's Dimensions.—The scantlings of the parts are governed by the dimensions D and h , which are adjusted for the extra depth in the way of the quarter deck.

Strength at the Break.—There is a natural weakness at the break of the quarter deck, and this must be compensated for.

The upper deck stringer, or bridge deck stringer, must extend for three or four frame spaces abaft the break and the quarter deck stringer plate must extend for a similar distance forward of the break.

The upper deck plating must overlap that of the quarter deck by two or three frame spaces and diaphragm plates must be fitted between them. These are to be attached to the decks and bulkhead by double angles and may also be required to have vertical stiffeners fitted to them.

The upper deck sheerstrake is made thicker and is extended for some distance abaft the break. If connected to a long bridge, the quarter deck sheerstrake must also be thickened and extended into the bridge.



TYPES OF PILLARING.

General.—Pillars are intended to support the deck above them and to tie the beams to the bottom, or deck below. They are usually fitted two or more beam spaces apart, so it is necessary to fit a deck girder, running fore and aft under the beams, to support the intermediate beams.

Ordinary Pillars.—All ships originally had one row of ordinary pillars fitted at the centre line. As ships became larger, these pillars were made heavier, or more rows of pillars were introduced.

Ordinary pillars have been mainly superseded by massed pillars. In ships built for the grain trade, however, a centre line row of pillars is sometimes fitted, in addition to the main system of massed pillars. These centre line pillars are usually "reeled," or fitted in pairs, with a channel runner at their heads in order to support shifting boards.

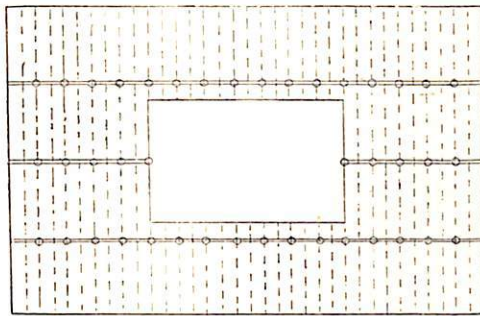
Quarter Pillars.—The large number of pillars required in ordinary pillaring obstructed the holds. This obstruction was reduced by fitting a system of larger pillars, spaced further apart, and fitted at the quarter line only. These were known as "quarter pillars." The deck girders have to be made stronger, with this type of pillaring, because of the increase of its unsupported span: that is, because each section, between pillars, has more beams to support.

Quarter pillaring is not used as a general system in modern ships, but it is often fitted in certain parts.

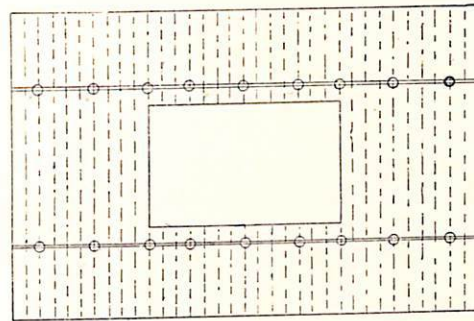
Massed Pillars.—The modern system of massed pillaring was developed from the quarter pillars by increasing their size and spacing still further. The deck girders have to be made very strong, because of their large unsupported span.

Massed pillaring may be fitted in line with the hatch coamings, in which case the coamings form a part of the deck girder.

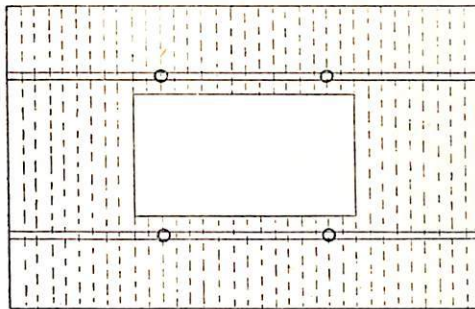
Middle Line Longitudinal Bulkheads.—Partial longitudinal bulkheads may be fitted at the centre line, in lieu of pillars. This is sometimes done in ships built for the grain trade, in order to facilitate the rigging of shifting boards.



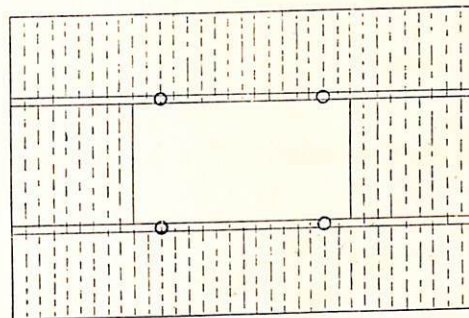
ORDINARY.



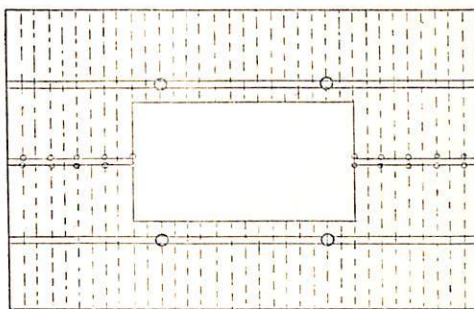
QUARTER LINE.



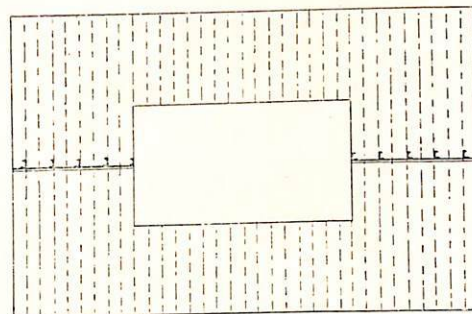
MASSED.



MASSED, IN LINE WITH COAMINGS.



MASSED AND PAIRS AT CENTRE LINE.



PARTIAL LONGITUDINAL BULKHEADS.

(DOTTED LINES SHOW BEAMS.)

TYPES OF PILLARING.

ORDINARY PILLARING.

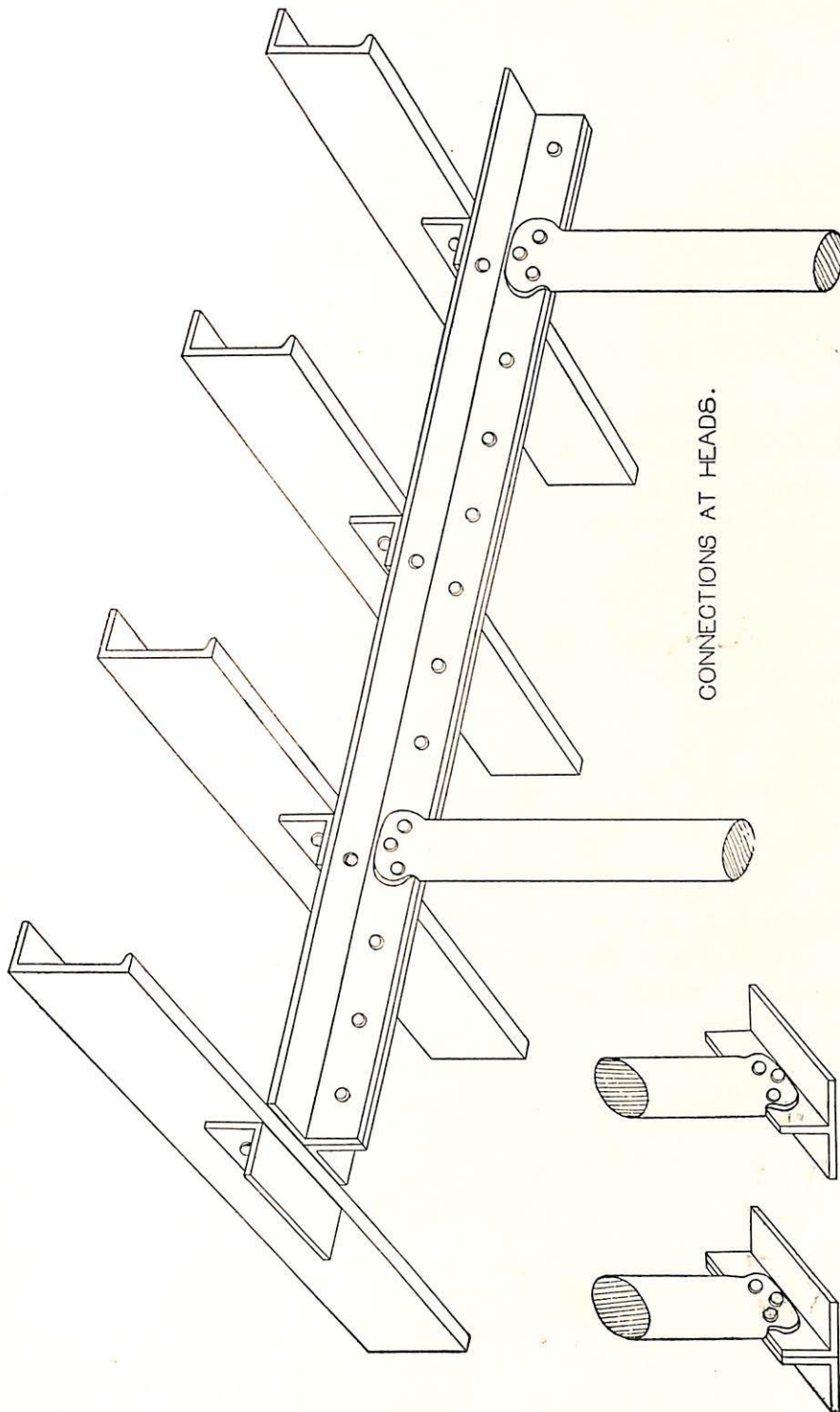
Pillars.—Ordinary pillars usually consist of solid round bars, fitted at alternate beams. Their heads and feet are “palmed,” or flattened, for attachment at the deck and inner bottom. Their heads are attached to the deck girder and their feet to double angles or T-bars.

Deck Girder.—This is often called a “deck runner” when used with ordinary pillaring. It may consist of a single angle, but is more often a bulb-angle, or double angles. It is usually attached to the deck beams and transverse bulkheads by angle lugs.

Size.—The diameter of the pillars varies from $2\frac{3}{8}$ inch to 6 inches. It is governed by the length of the pillar and the work which it has to do.

Riveting.—The angle lugs connecting deck girders to beams and bulkheads must have 2 rivets in each flange.

Pillars are to have from 2 to 6 rivets in each end, according to their diameter.



CONNECTIONS AT HEADS.

CONNECTIONS AT FEET.

ORDINARY PILLARS.

MASSED PILLARING.

Pillars.—These are usually formed of plates on the round, but any of the sections shewn in the sketches may be used.

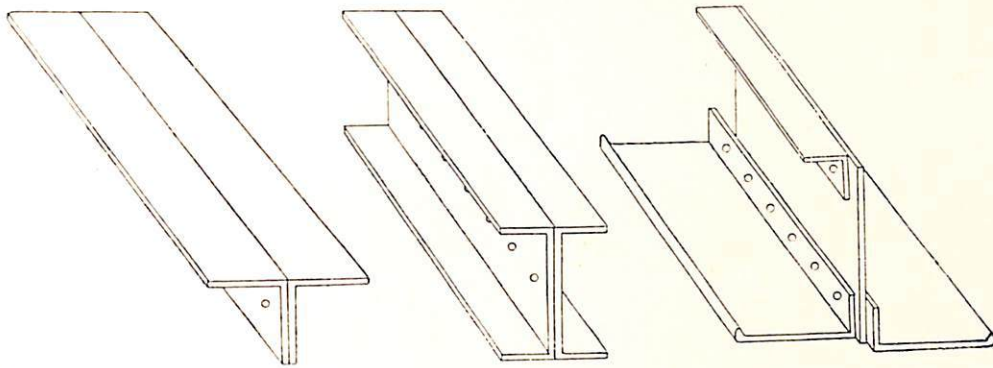
Deck Girders.—Double angles or double channels may be used. More often, the deck girder consists of an intercostal plate of between 10 and 36 inches deep. Its lower edge may be stiffened by a flange, or by one or two bulb angles.

Size.—The size of pillars and deck girders depends on the work they have to do : that is, by the length and width of deck supported by them and by the height of the 'tween decks above them. In the case of pillars, their length is also taken into consideration.

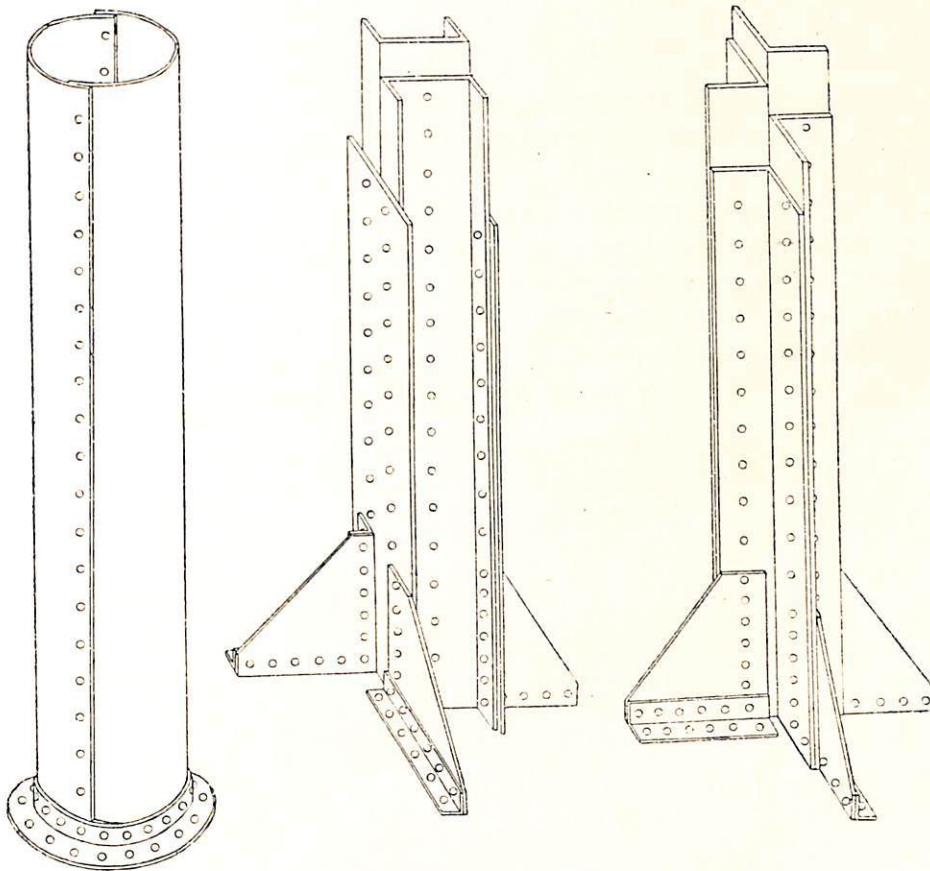
Fitting of Pillars.—Hollow, round pillars are connected at the head and foot by angles. Other types are connected by fore-and-aft and athwartships brackets.

It is usual to fit two or three pillars on each side in each hold. 'Tween deck pillars should be placed directly over lower hold pillars, if possible.

Doubling plates must be fitted to the inner bottom plating under the heels of massed pillars. The heels of the pillars should rest, if possible, on the intersection of a floor and existing intercostal girder in the bottom. If this is impossible, extra intercostal girderwork must be introduced to intersect the floor under the pillar.



DECK GIRDERS.

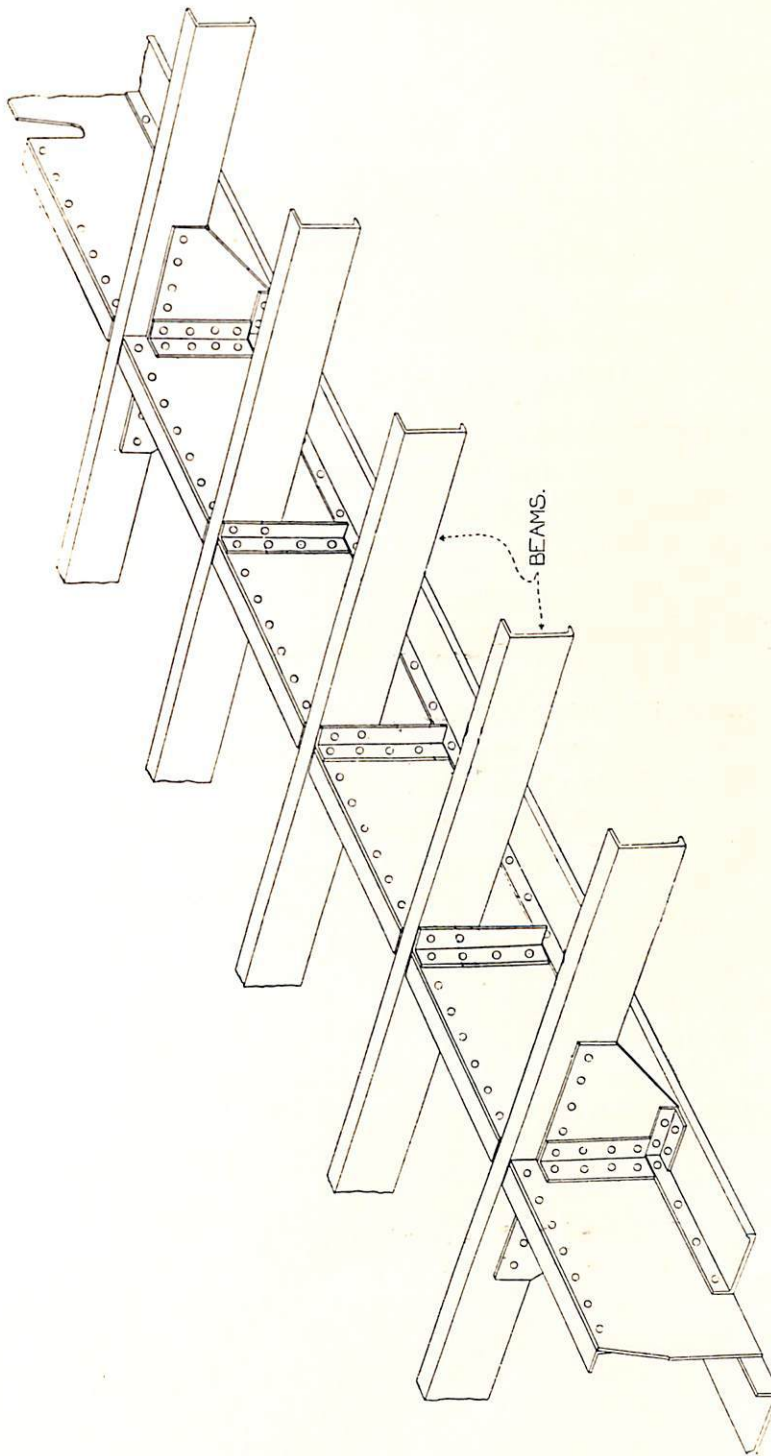


MASSED PILLARS.

MASSED PILLARING—*(Continued).*

Fitting of Deck Girders.—Girders formed by angles or channels are attached to the beams by angle lugs, except in the case of channel beams, to which they are riveted directly.

Intercostal plate girders are attached to the deck above by angles, which are intercostal between the beams. They are attached to the beams by angles, which extend to the bottom of the girder. If the girder has double bulb-angle stiffeners on its lower edge, brackets must be fitted between girder and beam at every fourth frame space. If the lower edge of the girder is flanged, or stiffened by single bulb-angles, brackets must be fitted at alternate frame spaces.



DECK GIRDER.

MASSED PILLARING—*(Continued).*

Deck Girders at Bulkhead.—Deck girders are cut at bulkheads. To maintain strength, they are attached to the bulkhead by double riveted brackets, which must be flanged on their inner edges.

Deck Girders at Hatchways.—When deck girders are more than 18 inches from the hatch coamings, the half-beams are reinforced, or the coamings deepened in order to transmit the loads from the hatchway to the girder.

Hatch Coamings as Deck Girders.—Deck girders are often fitted in line with the hatch coamings and the coaming plate is then built into the girder. In this case, the coaming has to comply with both the rules for the construction of hatch coamings and with those for deck girders.

Riveting.—The pitch of riveting is 5 diameters in the seams of tubular pillars and in the head and heel of all massed pillars.

In pillars built of channels or angles, the pitch is 7 diameters.

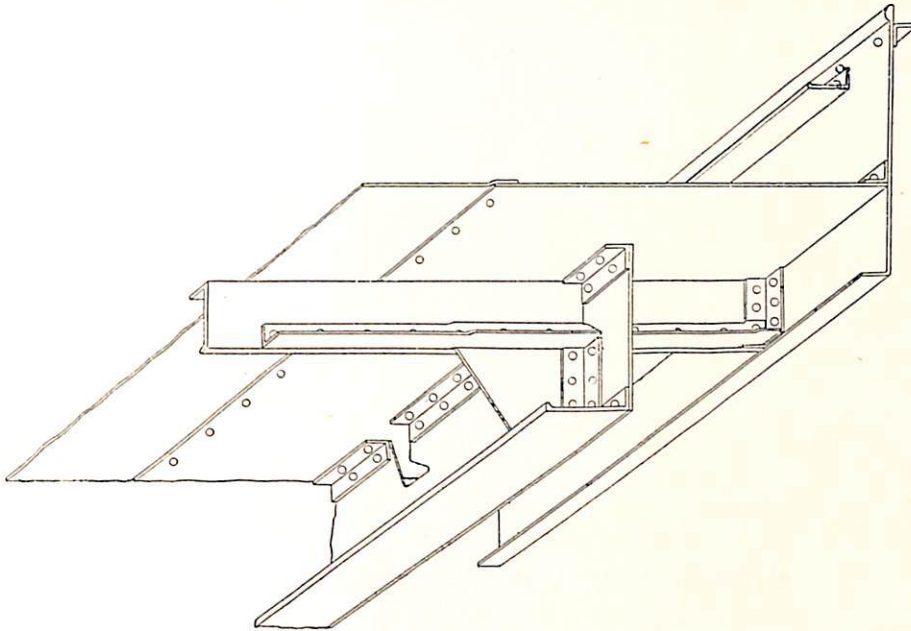
Connection of deck girder to deck—5 diameters.

Brackets at bulkheads—5 diameters.

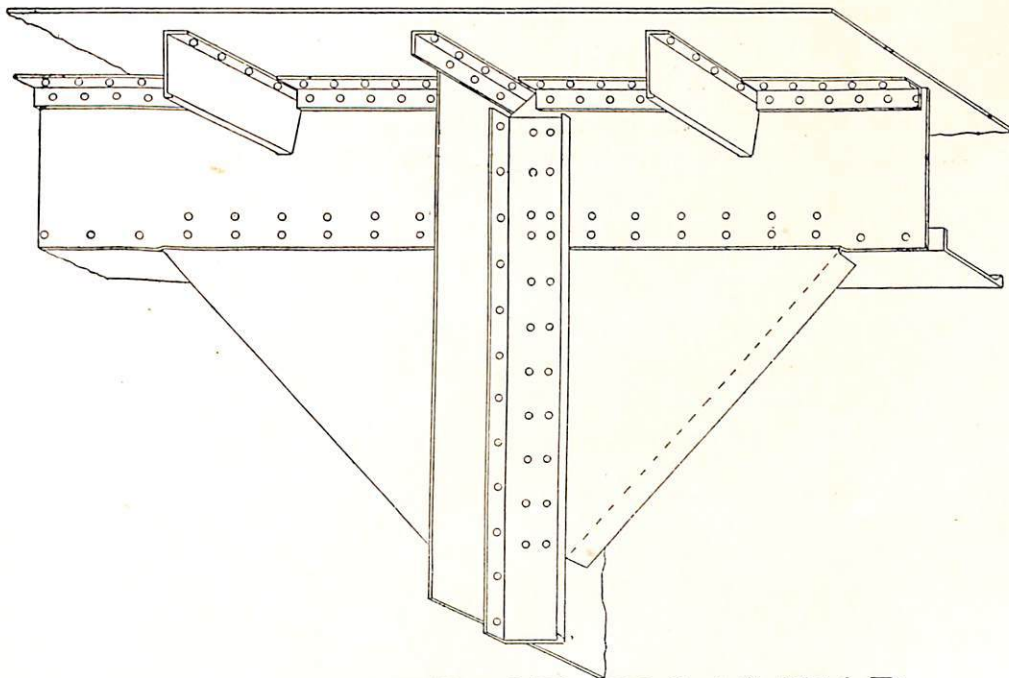
End laps in girders—4 diameters.

End laps in girders—4 diameters.

Other connections—6 or 7 diameters.



GIRDER OVER 18' FROM HATCH.



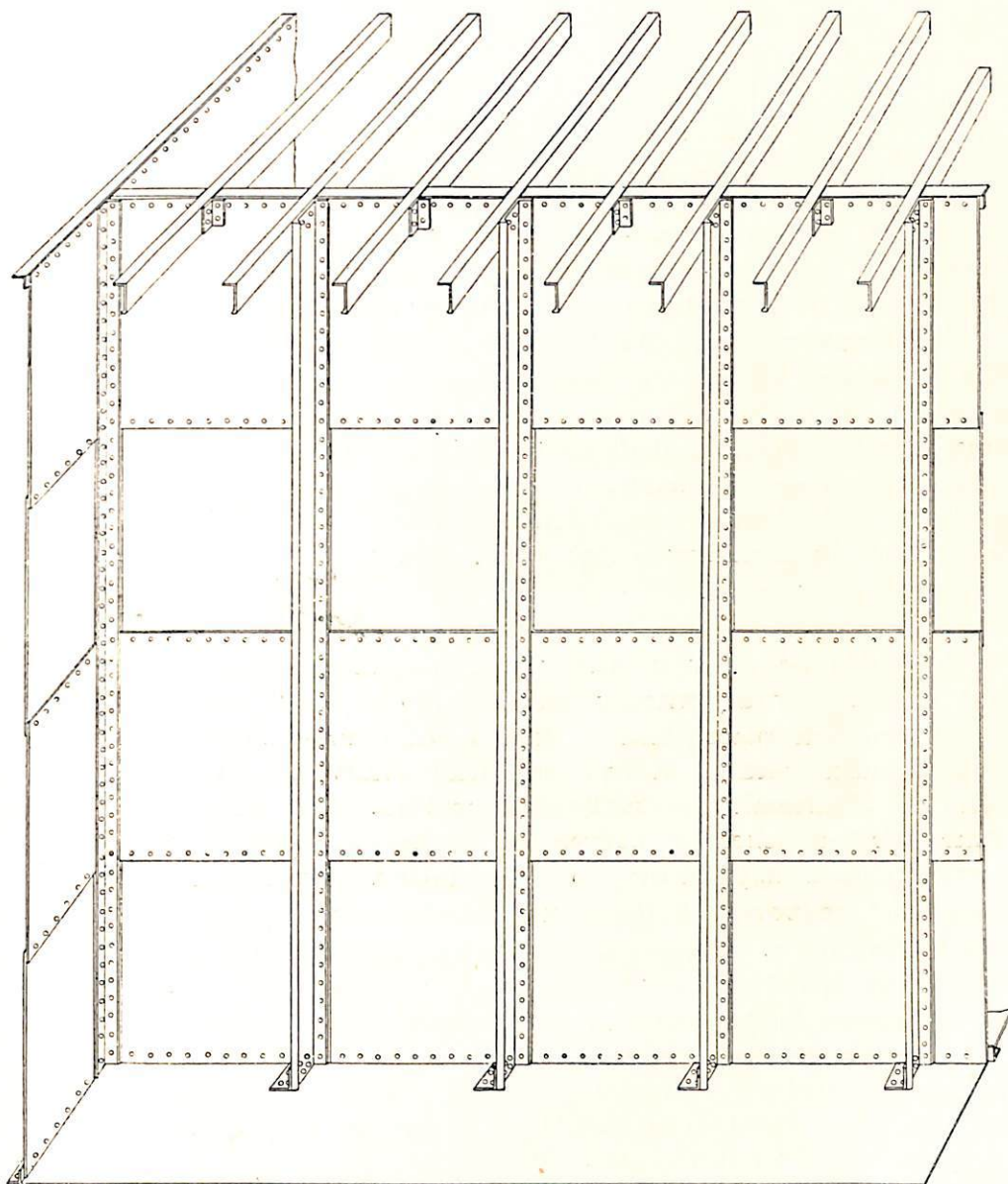
DECK GIRDER AT BULKHEAD.

MIDDLE LINE LONGITUDINAL BULKHEADS.

When middle line longitudinal bulkheads are fitted in lieu of pillars, they need not be made watertight.

The plating is to be .30 inch thick in the holds and .26 inch thick in the 'tween decks. It must be attached at the top and bottom by single angles.

Vertical stiffeners are to be fitted at alternate frame spaces when the frame spacing is less than 30 inches, and at every frame space when the frame spacing is more than 30 inches. These stiffeners are to be riveted to the beams, and attached by double-riveted lugs at the foot. At the ends of hatchways, they are to be attached by flanged brackets at the top and bottom.



LONGITUDINAL BULKHEAD.

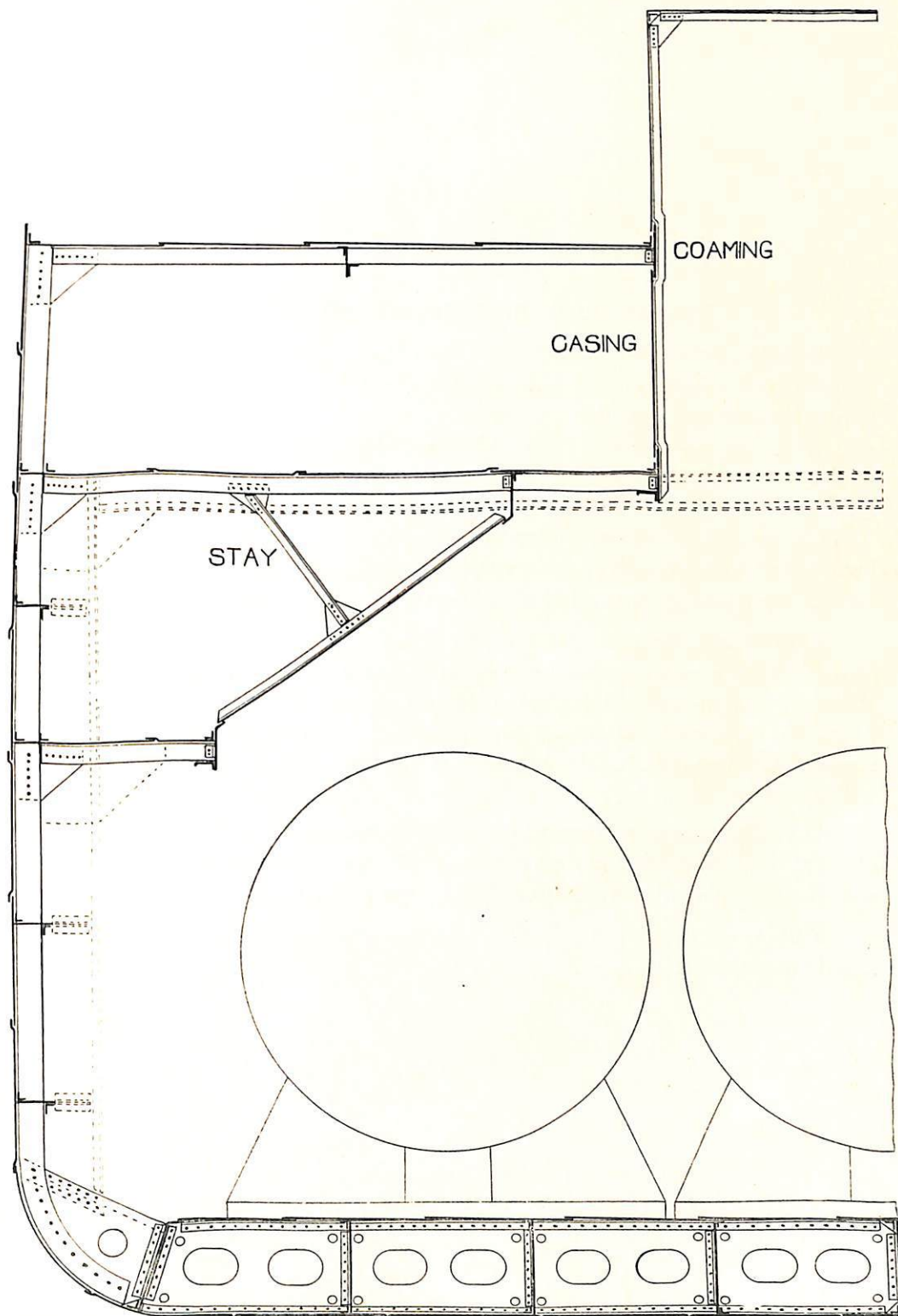
ENGINE AND BOILER ROOMS.

General Arrangements.—The structural arrangements of engine and boiler rooms vary greatly from ship to ship and depend on many things, so that the rules concerning them are necessarily rather vague.

It is always necessary to cut away decks in the way of machinery spaces. The lowest deck is often cut away considerably, if not completely, to clear the engines and boilers. The other decks must also be cut, but usually to a lesser extent, to provide a shaft for the admission of light and air, to allow the boiler uptakes and ventilators to pass through and to allow parts of the machinery to be lifted or removed during overhaul. The shaft thus formed is boxed-in by the machinery casings, which usually extend for the whole length of the machinery spaces.

In coal-burning vessels, the 'tween deck spaces between the casings and the ship's side are partly or entirely used as bunker spaces. If they are not used for coal, they are generally used for cargo or passenger accommodation.

'Tween deck spaces which are used as coal bunkers are filled by means of small "bunker hatches" in the upper deck; whilst in cargo vessels, a shoot, called a "saddleback", is usually also provided. This saddleback is placed either over the boilers, or between the engine and boiler rooms, and is fed through a small hatch in the top of the fiddley. Small coaling hatches, or "scuttles," are provided in the 'tween decks for trimming coal down from one deck to that below. The coal is usually brought down from the 'tween decks to the firing platform in the stokehold by means of vertical trunkways, called "pocket bunkers," which extend down the ship's side on either side of the stokehold. If the 'tween decks do not provide enough bunker space, a small hold, called a "cross bunker," is built, forward of the boiler room. In this case, pocket bunkers are not fitted, as the coal is brought down to the firing platform through the cross bunker.



BOILER ROOM.

ENGINE AND BOILER ROOMS—(Continued).

Double Bottoms.—These must be strengthened against heavy local weights and vibration and thickened against the excessive corrosion which is likely to occur in machinery spaces.

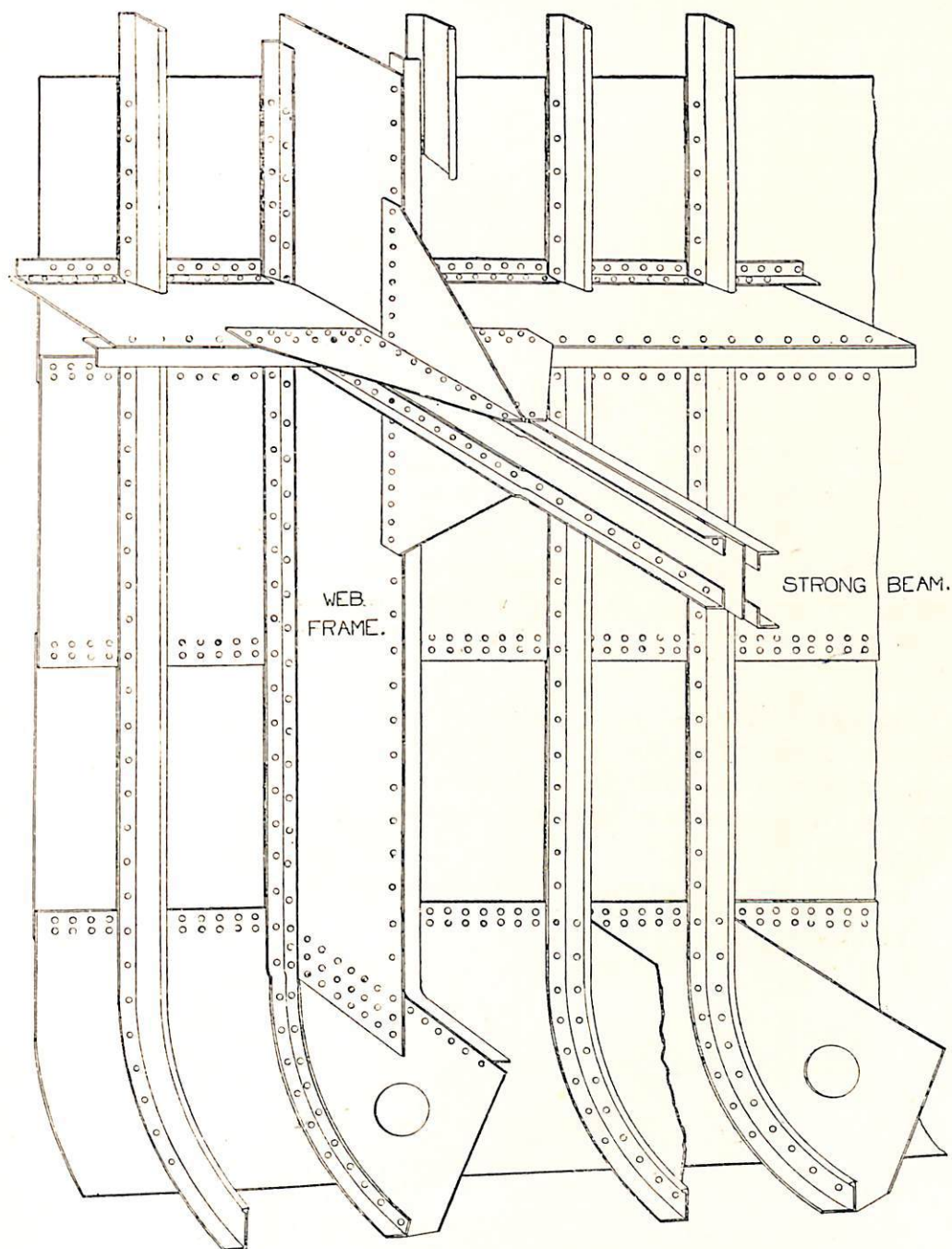
In boiler rooms, the tank side brackets and all parts of the cellular double bottom, inside and including the margin plate, are thickened. In engine rooms, the inner bottom plating only is thickened.

Under engine rooms, boiler bearers and thrust blocks, solid floors must be fitted at every frame space and their reverse bars must be doubled. Extra fore and aft side girders must also be fitted under engines and thrust blocks.

Frames and Beams.—Frames are thickened in boiler rooms and also in coal bunkers where excessive corrosion is likely to occur. Loss of transverse strength, due to the cutting away of frames and beams, is compensated by fitting web frames and strong beams wherever possible. When permanent strong beams cannot be fitted, portable ones, bolted in place, are often fitted within the casings.

Casings.—These are formed by fitting coamings, similar to hatch coamings, at each deck and by riveting fore and aft plates between them. They are stiffened by vertical angles, spaced 30 inches apart.

Pillars.—A system of pillaring, or some arrangement in lieu of it, must be fitted throughout.



FRAMING IN ENGINE ROOM.

SHELL PLATING.

Lloyd's Dimensions.— L , D and d .

Clinker Plating.—Clinker Plating was tried in the early iron ships. It is now obsolete for shell plating, as it requires tapered liners and is difficult to fit.

In-and-Out Plating.—This is sometimes termed "Raised and Sunken Plating." It is still used, but is gradually giving way to joggled systems. Liners are fitted between the out-strakes and the frames to give a proper connection.

Joggled Plating.—Joggled plating does not require liners and is thus cheaper and lighter than the in-and-out system. It has the disadvantage that special machinery is needed to joggle the plates, so that if the plating be damaged, it is impossible to have proper repairs made in some ports.

Joggled Framing.—Joggled framing has all the advantages of joggled plating and is also easy to repair. It is now very largely used.

Flush Plating.—This is sometimes used for yachts, where appearance is required. It is heavy and expensive and is never used for merchant ships.



IN AND OUT.

JOGGLED PLATES.

JOGGLED FRAMES.

FLUSH.

SHELL PLATING.

SHELL PLATING—(*Continued*).

Stealer Plates.—The girth of the ship decreases towards the ends and so the width of plates must be decreased in these parts. To save making the plates ridiculously narrow at the ends, it is usual to run pairs of adjacent strakes into one.

The above is more difficult than it sounds, as it means combining an in-strake with an out-strake to give an in-and-out strake. This is done by means of a stealer plate, one type of which is shown in the sketch. Note how the tapered liners are used.

Special Strakes.—Garboard strakes are the strakes of plating next to the keel, on either side.

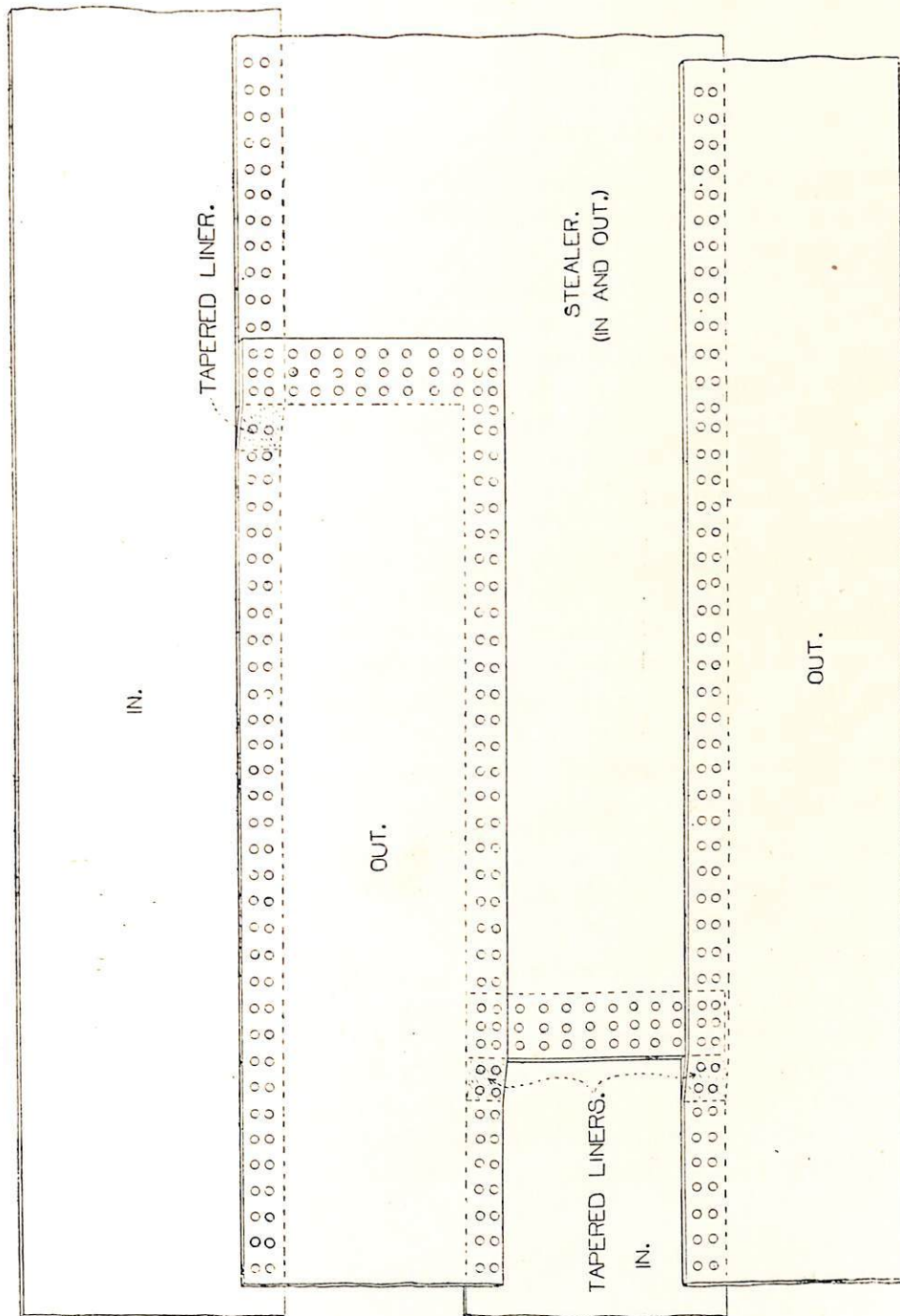
Sheer strakes are the upper strakes of shell plating on either side, next to the upper deck.

Special Plates.—Shoe plates are used to connect stem bars to flat plate keels. For further details, see "Stems."

Coffin plates are used to connect stern frames to flat plate keels. (See "Stern Frames").

Boss plates are plates fitted around the boss of the stern frame, which takes the propeller shaft.

Oxter plates are peculiarly curved plates which are fitted where the stern frame meets the counter.



STEALER.

SHELL PLATING—*(Continued).*

Thickness.—Shell plating varies in thickness in different parts of the ship, whilst certain plates and strakes are made thicker than normal.

When the plating is .56 inch, or less in thickness, it is maintained at the same thickness from the sheerstrake to the keel plate. When the plating is thicker than this, the strakes between the upper turn of the bilge and the sheerstrake are made slightly thinner than those of the bilge and bottom.

All shell plating must be kept at its midship thickness for four-tenths of the ship's length amidships, but may be slightly reduced towards the ends of the ship. The three strakes of plating next to the keel, however, are kept at their midship thickness right forward to the collision bulkhead, as a precaution against pounding.

The sheerstrake is made thicker than the other strakes for four-tenths of the ship's length amidships, but may be gradually reduced to the same thickness as the other plating at the ends of the ship.

Flat plate keels are thicker than other strakes. Garboard strakes are also made thicker when a bar keel is fitted, but not with a flat plate keel.

Boss plates of single screw ships and the plates on the spectacle frames of twin screw ships are thickened to resist vibration.

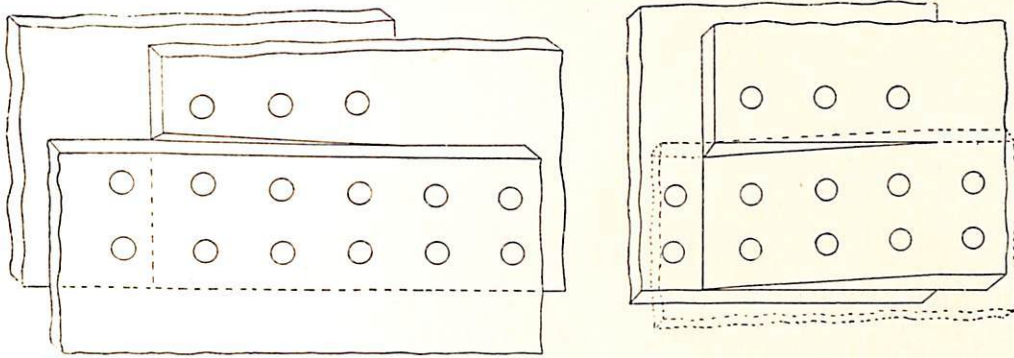
Plating is doubled or thickened in the way of hawse pipes.

Breadth.—Lloyd's Rules only lay down a definite breadth for keel plates, garboard strakes and the sheerstrake. Other strakes may be of any reasonable breadth.

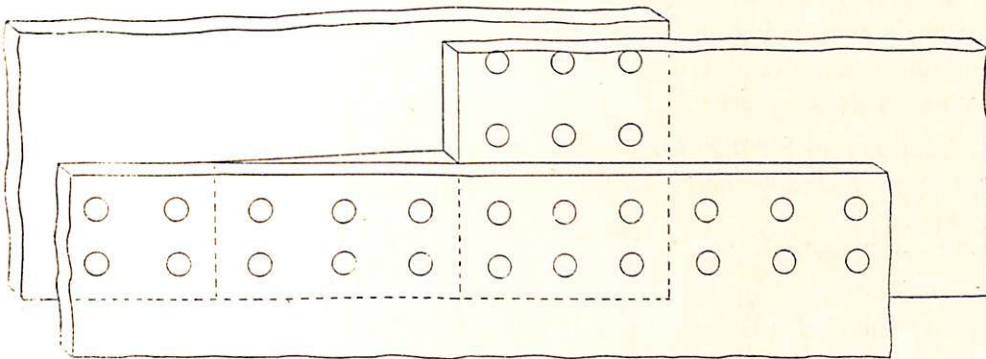
Fitting.—It is difficult to make a watertight joint where a landing edge crosses an end lap. This difficulty is overcome by either scarphing the corner of one plate, or by fitting a tapered liner.

Where liners are fitted between shell plating and frames, they must be in one piece and must be of the same width as the flanges of the frames.

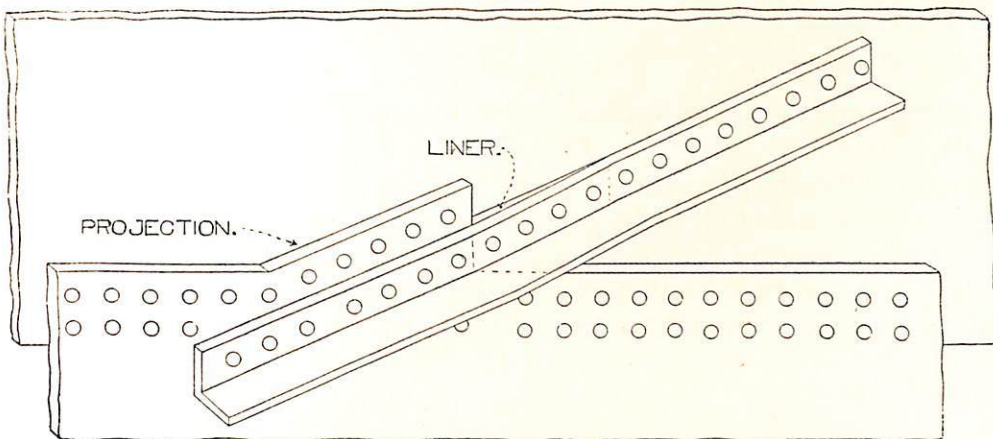
When watertight angles, such as margin angles, cross the landing edges of shell plating, special arrangements are made to preserve watertightness. (See sketch.)



LANDING EDGE CROSSING END LAP - SCARPHED PLATE.



LANDING EDGE CROSSING END LAP - TAPERED LINER.



WATERTIGHT ANGLE CROSSING LANDING EDGE.

SHELL PLATING.

SHELL PLATING—(Continued).

Shift of Butts.—Butts must be as widely spaced as possible, in order to avoid undue weakening of the plating. Butts in adjacent strakes must not be closer than two frame spaces apart; whilst the butts of the sheerstrake must be at least two frame spaces from those of the deck stringer.

To provide an adequate shift of butts, the shell plates are usually made as long as is reasonably possible and a length of about ten frame spaces is common. In many modern ships, the butts are welded, even though the seams may be riveted.

Openings in Shell Plating.—Any openings cut in the shell plating must have special arrangements to preserve strength and their corners must be rounded.

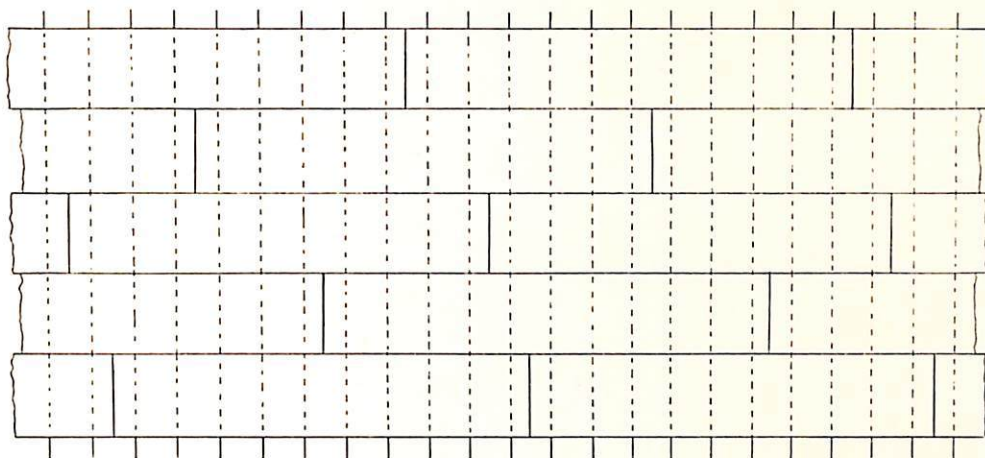
When large openings, such as cargo doors, are cut in the plating, they are usually framed by an angle bar. Often, web frames are fitted on either side and the shell plating is doubled above and below the opening.

Numbering of Strakes and Plates.—Strakes are distinguished by letters from the keel outwards, the garboard strake being strake "A." The plates in each strake are usually numbered from aft to forward.

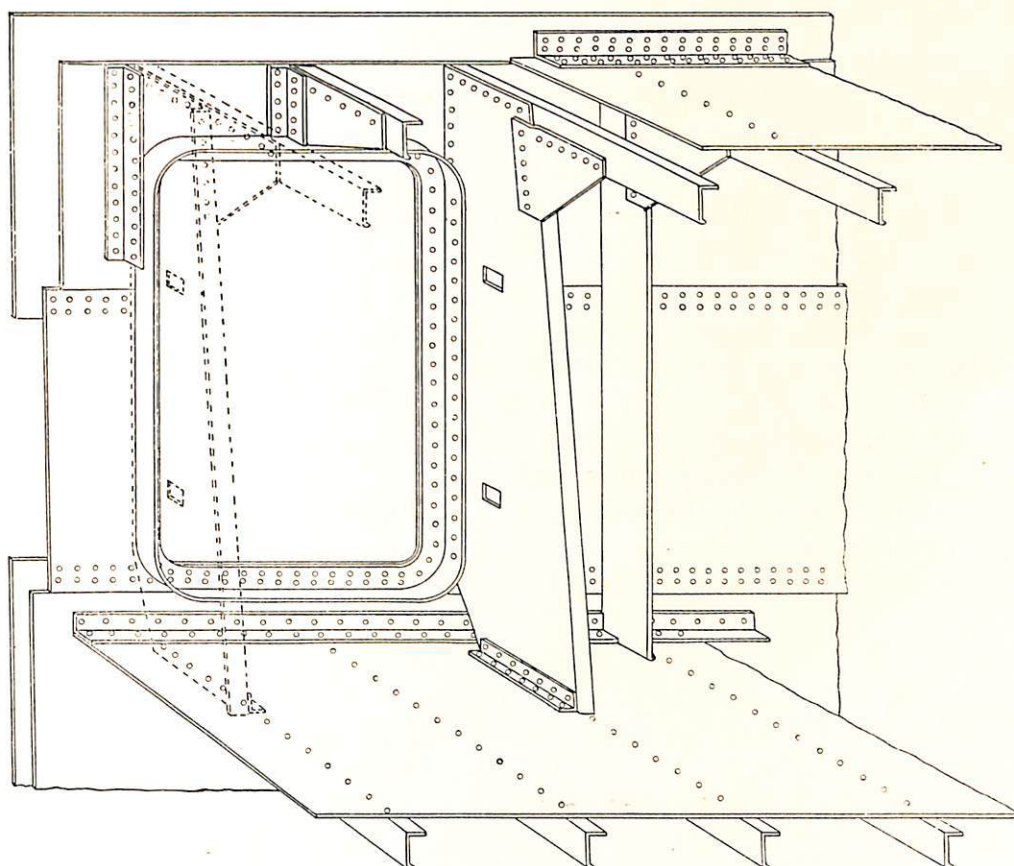
For example, plate "5D" would be the fifth plate from aft in the fourth strake from the keel.

Riveting.—Seams are double riveted in ships of 275 feet and more in length, with a pitch of not more than $4\frac{1}{2}$ diameters. In ships of over 500 feet in length, extra riveting is required in three seams nearest the neutral axis, for one quarter of the ship's length in the fore and after body.

End laps must be double to quintuple riveted, according to the thickness of the plates and their position in the ship. The pitch of the rivets must be 4 diameters, except in quintuple riveted laps, where it may be $4\frac{1}{2}$ diameters.



SHIFT OF BUTTS.



FRAMING OF CARGO DOOR.

BILGE KEELS.

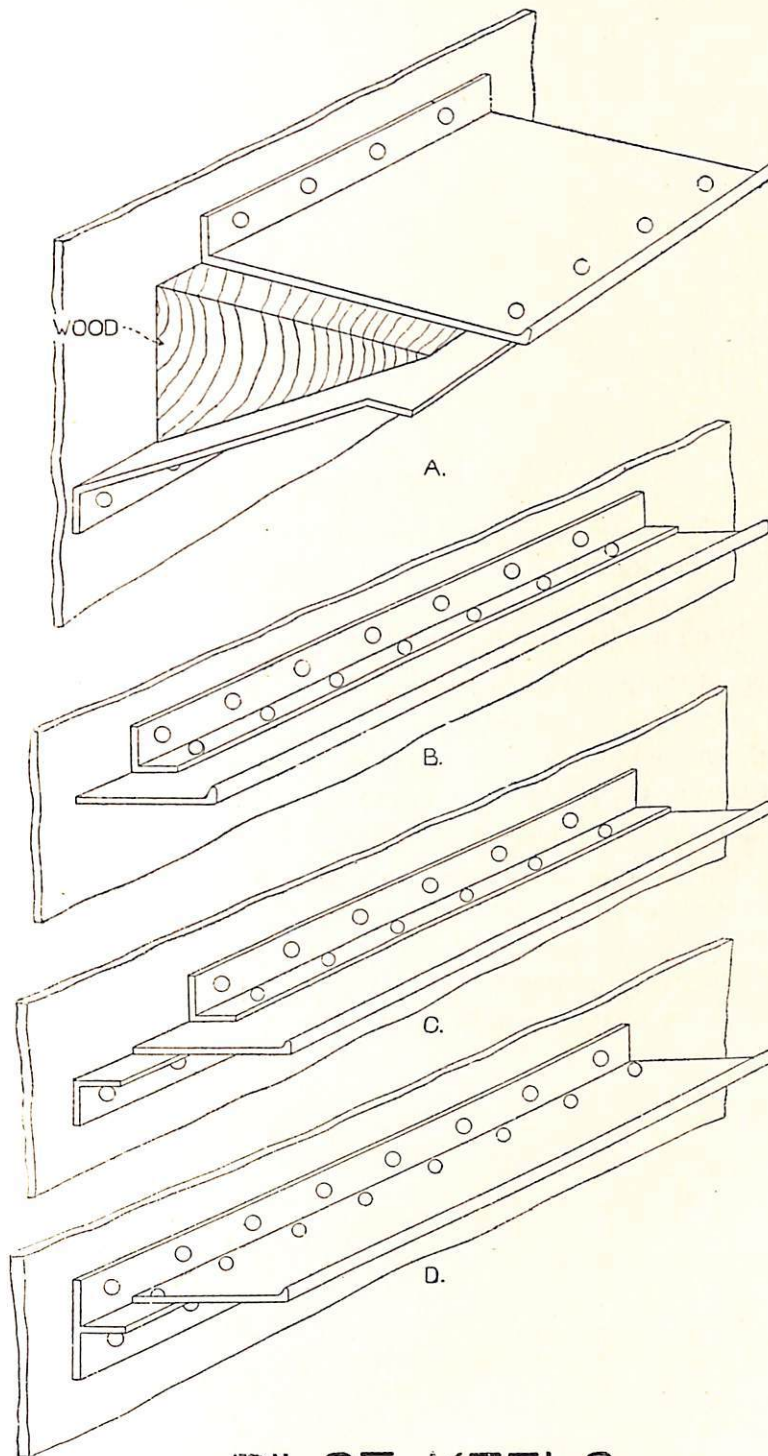
Purpose.—Bilge keels are intended to resist rolling. Their effects are complex, but may be summarised as follows :—

- (a) Direct resistance between bilge keel and water has a comparatively weak effect.
- (b) They slightly increase the ship's period of roll.
- (c) They upset the transverse streamlines of the ship's hull and thus set up eddy-currents and increase the "wave making resistance."
- (d) They increase water pressure over a large area of the ship's hull and this pressure acts in such a direction as to damp the rolling.

Construction.—The sketches show various types of bilge keels. Type "A" is used in warships and very large merchant ships. The other types shown are the ones in general use for ordinary ships.

Note that in the ordinary types, the angle or T-bar is strongly connected to the shell plating, but only weakly connected to the bulb-plate. This is done so that if the bilge keel be ripped off, it will part at the outer joint. This reduces the risk of damage to the shell connection and of consequent leakage.

It is becoming common practice to weld the bilge keel directly to the ship's shell plating, instead of riveting it.



BILGE KEELS.

PLATED BULWARKS.

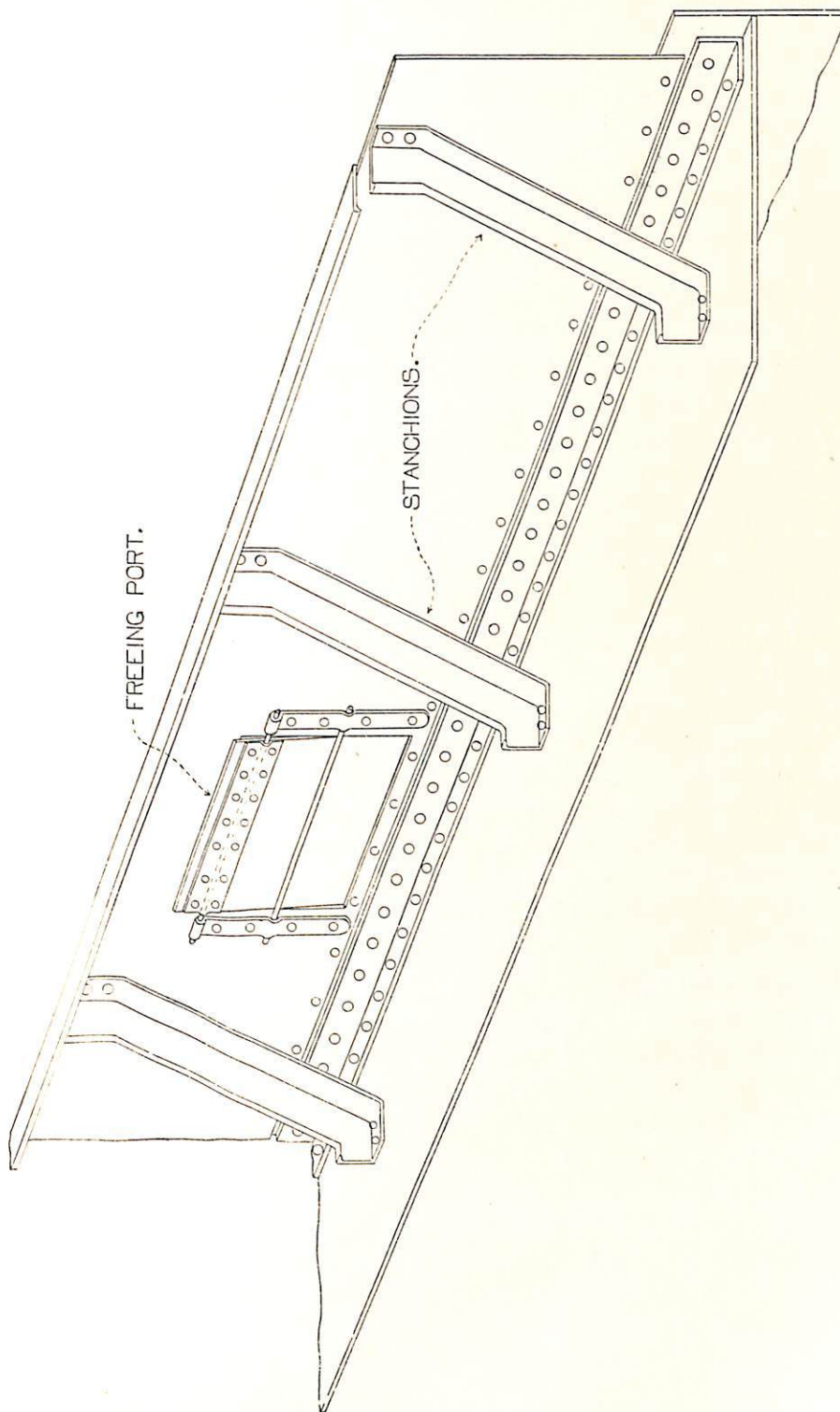
Fitting.—The sketch shows the usual method of fitting bulwark plates. The stanchions supporting the bulwark are not to be more than 6 feet apart. Those nearest the ends of long bridges or long poops must be within 5 feet of the bulkhead and are to be web plates.

Openings in Plates.—Where mooring pipes are fitted, the plating is to be doubled or thickened around them.

Where both the bulwark plate and the rail are cut, as for cargo gangways, the stays at the ends of the openings are to be made stronger.

Openings in bulwark plates are to be kept well away from break bulkheads.

Freeing Ports.—The area of freeing ports on each side depends on the length of the well deck. The lower edges of the ports must be as near to the deck as possible. Bars, spaced not more than 9 inches apart, must be fitted across the port. Where hinged flaps are fitted, they are to have brass pins and must not have any fittings for keeping them closed.



PLATED BULWARK.

WATERTIGHT BULKHEADS.

Uses.—Bulkheads are an important element of transverse strength, particularly against racking stresses. By dividing the ship into longitudinal subdivisions, they also give protection against fire and foundering.

Number to be Fitted.—All ships must have certain bulkheads, as follows :—

A collision bulkhead, ^{NOT LESS} at least 5 per cent. of the ship's length abaft the stem at the load waterline.

An after peak bulkhead, to enclose the shaft tube in a watertight compartment.

One bulkhead at each end of the machinery space.

Ships of between 285 and 335 feet in length are to have an additional bulkhead half-way between the boiler room and collision bulkheads (5 bulkheads in all).

Ships of 335 to 405 feet in length are to have two additional bulkheads, one forward and one aft. (6 bulkheads in all.)

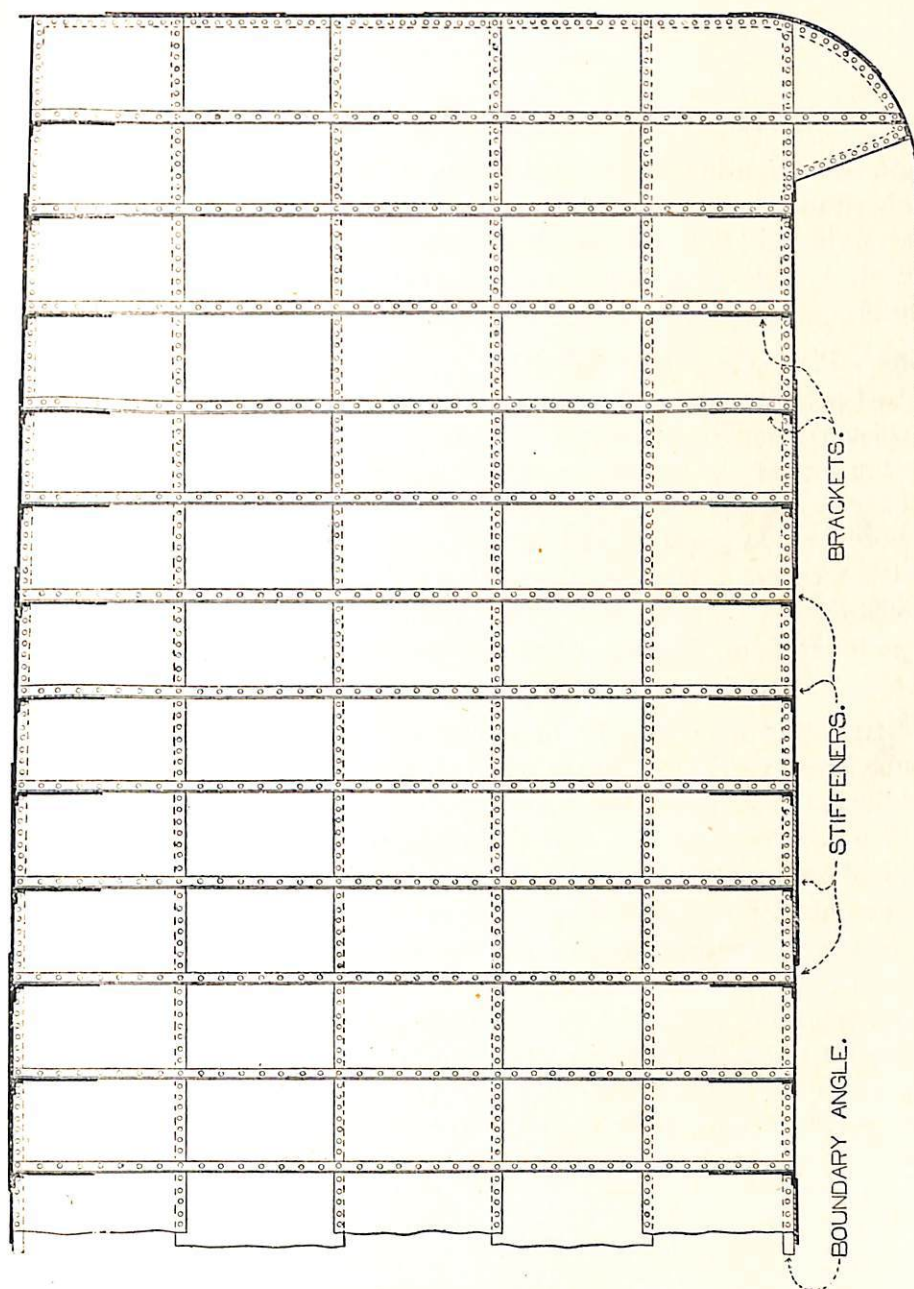
Ships of 405 feet to 470 feet length must have 7 bulkheads in all.

Ships of 470 feet to 540 feet length must have 8 bulkheads in all.

Ships of 540 feet to 610 feet length must have 9 bulkheads in all.

Ships having the machinery aft are to have an additional bulkhead midway between the collision bulkhead and engine room bulkhead, if they are between 220 feet and 285 feet in length.

Passenger Ships.—The spacing quoted above is the minimum required for all ships. The Ministry of Transport, however, require passenger ships to be subdivided by watertight bulkheads in accordance with the "permissible length" of compartments. This is found by multiplying the "floodable length" by the "factor of subdivision." (See pages 203 and 204.)



WATERTIGHT BULKHEAD.

WATERTIGHT BULKHEADS—(Continued).

Height.—Collision bulkheads must extend to the upper deck. The after peak bulkhead need only extend to the first deck above the load water line, if it forms a watertight flat. All other bulkheads must extend to the uppermost continuous deck, unless the ship has a shelter deck, or its equivalent, when the bulkheads may extend to the second deck.

Plating.—Plating may be fitted either vertically or horizontally, but it is usually fitted horizontally, as this allows of a better graduation of thickness.

The thickness may be graduated, increasing from the top downwards. It is governed in each strake by the spacing of the stiffeners and the depth of the bottom of the strake below the top of the bulkhead.

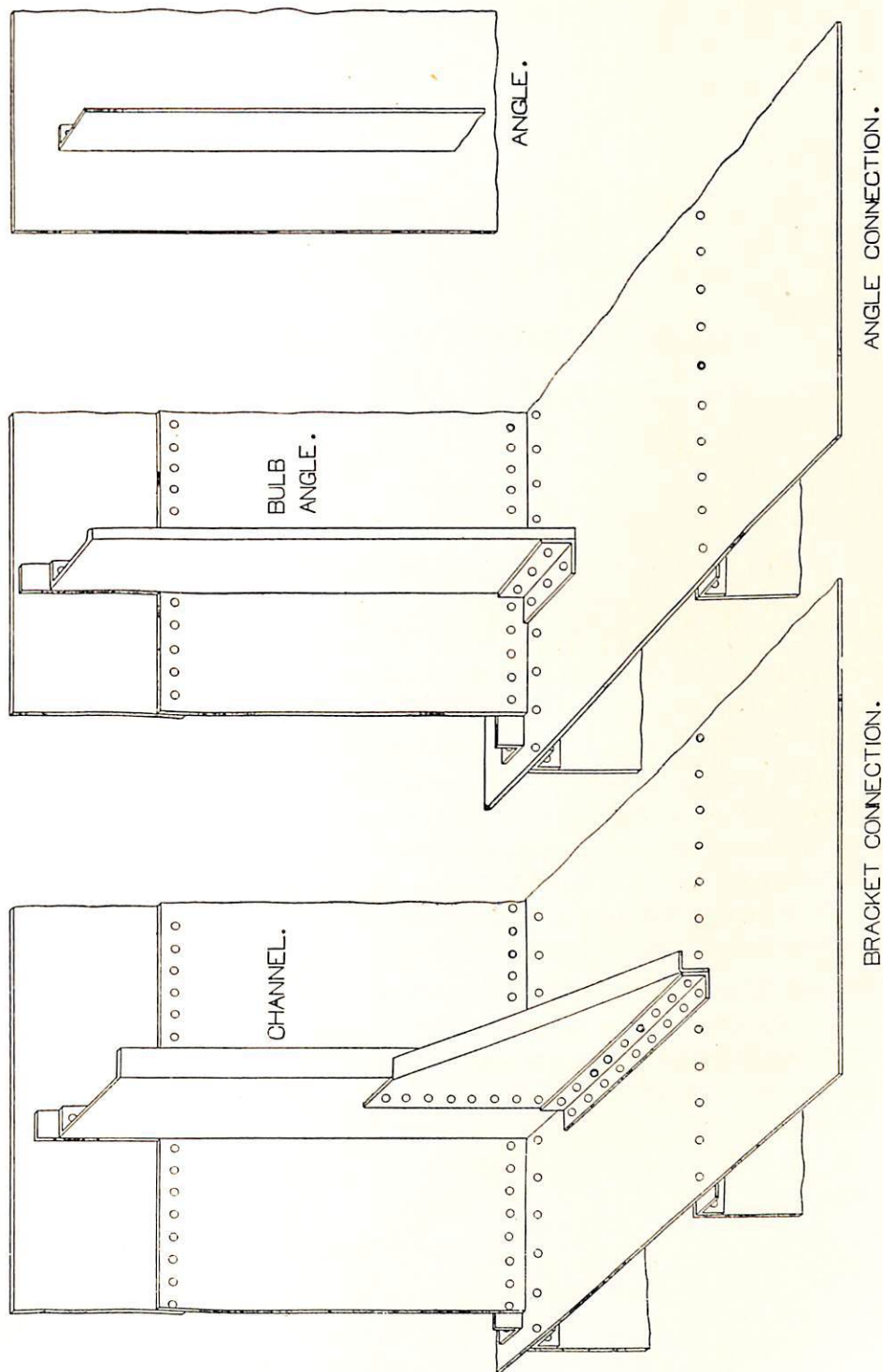
The lowest strake must extend 36 inches above the top of the cellular double bottom, except where the latter only exists on one side of a bulkhead, when it must extend 12 inches above the tank top plating.

Plating in after peak bulkheads must be doubled or thickened around the stern tube to resist vibration.

Stiffeners.—Stiffeners may be of angle, bulb-angle or channel section and must be fitted vertically. Their type and size depend on the distance of the top of the bulkhead above the top of the stiffener and on the actual length of the stiffener. They may be spaced 30 inches apart, except in collision bulkheads and deep tank bulkheads, where the spacing is to be 24 inches.

Stiffeners must be connected to the inner bottom, or deck plating, by either angle lugs or brackets. Where brackets are used for this purpose, they are to extend to the floor next to the bulkhead, or over a beam space. The breadth and depth of the brackets is to be two and one half times the depth of the stiffener, and brackets of over $22\frac{1}{2}$ inches in depth are to be flanged.

If stiffeners are cut for watertight doors, etc., the openings must be framed strongly and must have vertical, tapered web plates, extending well above the opening, fitted on each side.



BULKHEAD STIFFENERS.

WATERTIGHT BULKHEADS—(Continued).

Boundary Angles.—These may be single angles. They are single riveted to a depth of 35 feet below the top of the bulkhead, but below this they must be double riveted in both flanges.

At the corners of the bulkhead, the boundary angles are cut and a short piece of angle, bent and welded to the required shape, is fitted in.

Pipes Passing Through Bulkheads.—Where pipes pass through bulkheads, they are to be fastened to the bulkhead by studs or bolts screwed through tapped holes in the plating. They must not be secured by ordinary bolts passing through clear holes in the plating. This ensures that, if the bolt breaks, part of it will be left in the bulkhead ; otherwise, a clear hole might be left in the plating.

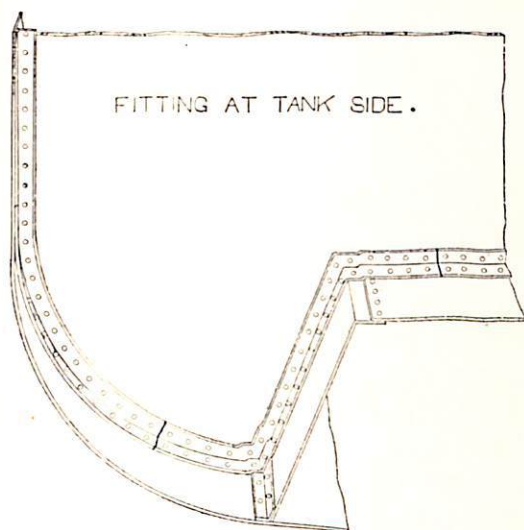
Riveting.—Plating is single riveted to a depth of 35 feet below the top of the bulkhead, but below this all vertical connections must be double riveted. The pitch of riveting in plating is $4\frac{1}{2}$ diameters.

Stiffeners to bulkhead, 7 diameters.

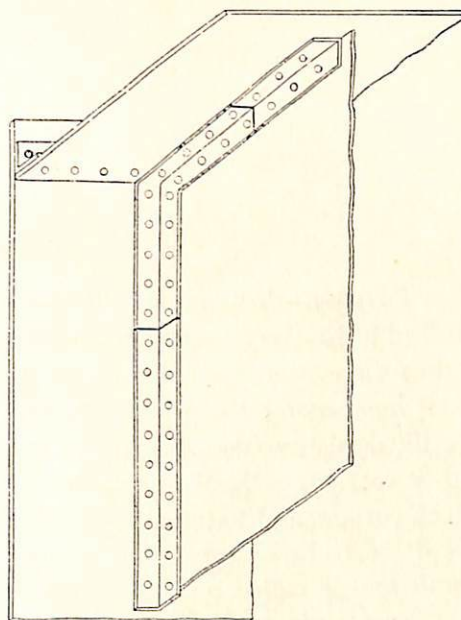
Boundary bars to bulkhead, $4\frac{1}{2}$ diameters.

Boundary bars to shell, 5 diameters.

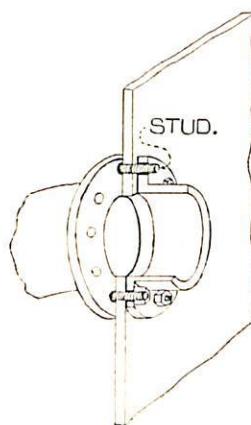
Tests.—Bulkheads forming tank boundaries are tested by testing the tank. Peak bulkheads, other than those forming peak tank boundaries, are tested by filling the peak to the level of the load waterline. Other watertight bulkheads are hose-tested.



FITTING AT TANK SIDE.

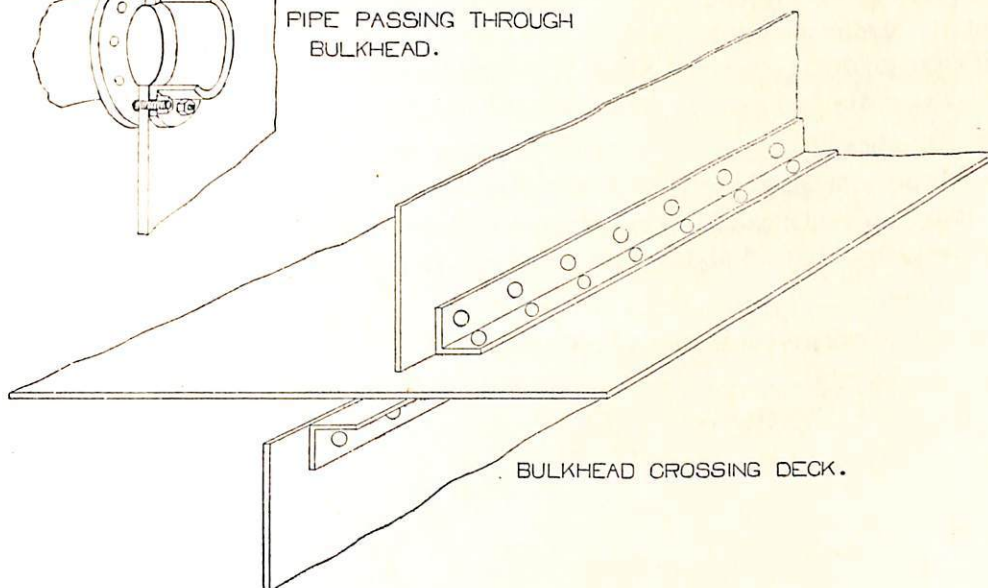


FITTING AT DECK CORNER.



STUD.

PIPE PASSING THROUGH
BULKHEAD.



BULKHEAD CROSSING DECK.

BULKHEADS.

DEEP TANKS.

Purpose.—When a ship makes a voyage in a light condition, it is usually desirable to carry a certain amount of water ballast. If the double bottom tanks alone were used for this purpose, the ship might be unduly “stiff”; so it has become the practice to arrange one of the lower holds so that it can be filled with water when necessary. This permits a large amount of ballast to be carried, without unduly lowering the centre of gravity of the ship. The deck corners and hatchway have to be made watertight and washplates must be fitted to break up “free surface effect,” so that the hold used resembles a tank and is called a “deep tank.”

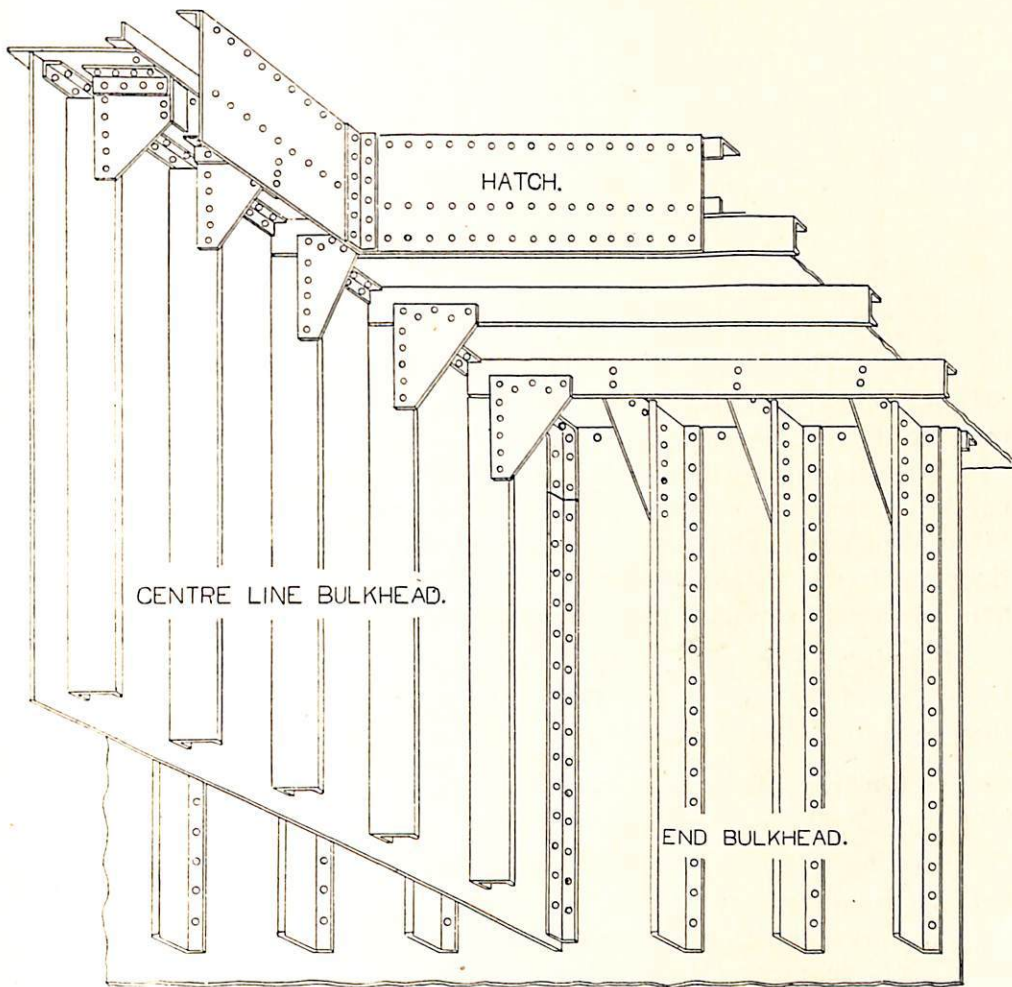
In certain trades, it has been found convenient to utilise deep tanks for the carriage of liquid cargoes, or for oil fuel bunkers. In other trades, the deep tanks are still used solely for their original purpose: to carry dry cargoes normally, but to be used as water ballast tanks when the ship is light.

When used for its original purpose, the deep tank is slightly strengthened, but its arrangements are similar to those of a normal hold, except for the differences already mentioned. If it is used for liquid cargoes or fuel, however, it is necessary to provide special strengthening within it.

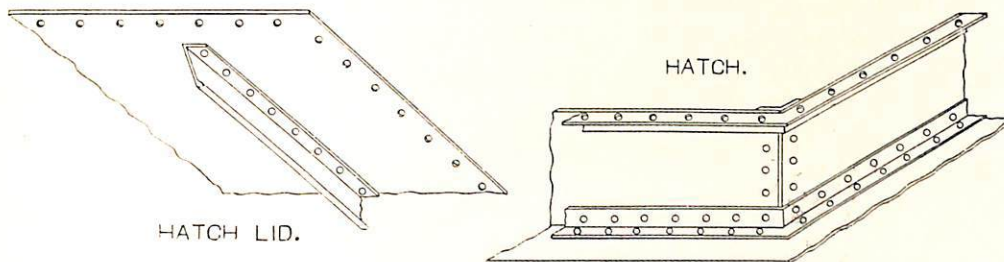
Bulkheads.—Deep tank bulkheads are similar to ordinary watertight bulkheads except that the stiffeners are always attached at their head and foot by brackets, whilst their spacing is decreased to 24 inches. The pitch of rivets in bulkhead plating and stiffeners is also slightly decreased.

Frames.—These must be made 15 per cent. stronger than normal and the spacing of rivets in them is decreased.

Beams.—Beams may be normal, but their size must not be less than that of the bulkhead stiffeners.



BULKHEADS AND HATCH COAMING.



DEEP TANKS.

DEEP TANKS—*(Continued).*

Decks.—The deck plating which forms the tank top must be at least .04 inch thicker than that of the boundary bulkheads. It must not, in any case, be thinner than normal.

In order to secure watertightness at the deck corners, the frames are often cut below the deck so that a continuous watertight stringer angle can be fitted. The frames above are then attached to the deck by brackets. Sometimes the frames extend through the deck in the usual way, and watertightness is secured by welding plates or angles around them.

Pillaring.—The beams must be supported by an intercostal girder on either side of the centre line. This girder may be supported by pillars, but these are often omitted and the girder deepened instead.

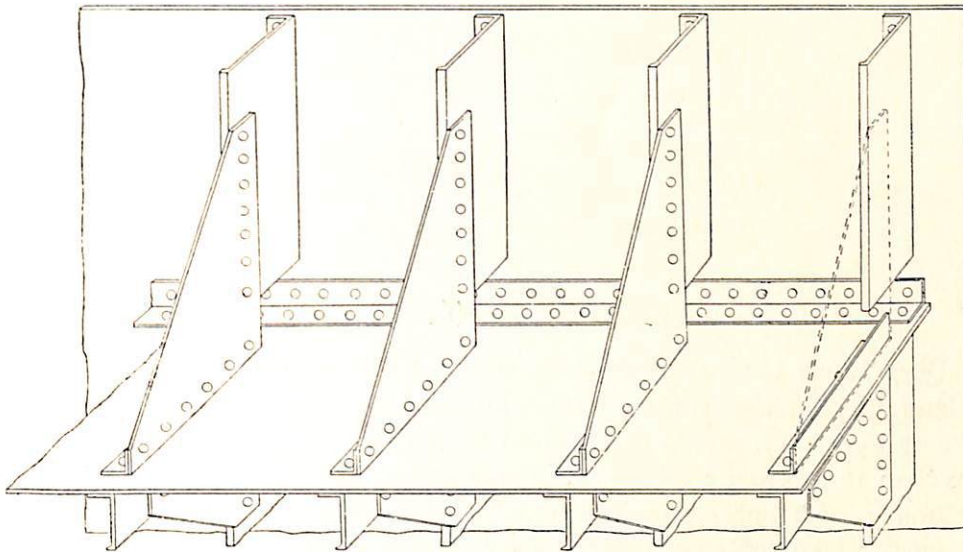
Washplates.—These must be fitted at the centre line, if the breadth of the tank exceeds 30 feet.

Riveting.—The pitch of rivets in the end laps of bulkhead plating must not exceed 4 diameters.

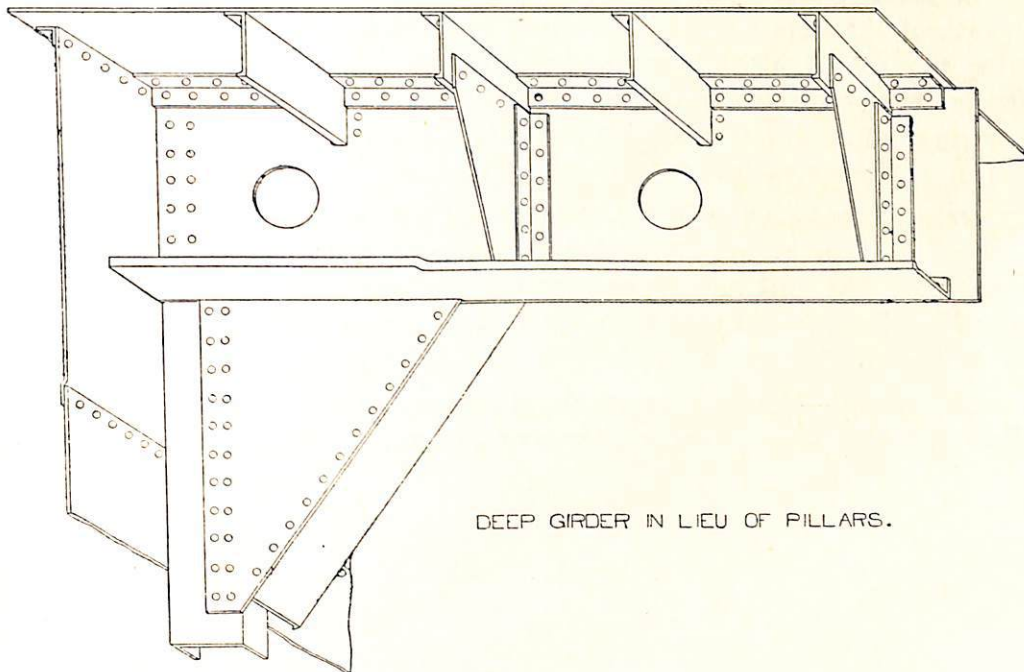
Rivets connecting stiffeners to plating must have a pitch of 6 diameters.

Rivets connecting frames to shell plating must have a pitch of $5\frac{1}{2}$ diameters.

Testing.—Deep tanks are tested by filling them with water to the maximum head which can come on them in practice ; provided that this is not less than from 3 to 8 feet above the tank top, according to the depth of the ship.



SECURING WATERTIGHTNESS OF TANK TOP.



DEEP GIRDER IN LIEU OF PILLARS.

DEEP TANKS.

DEEP TANKS—*(Continued).*

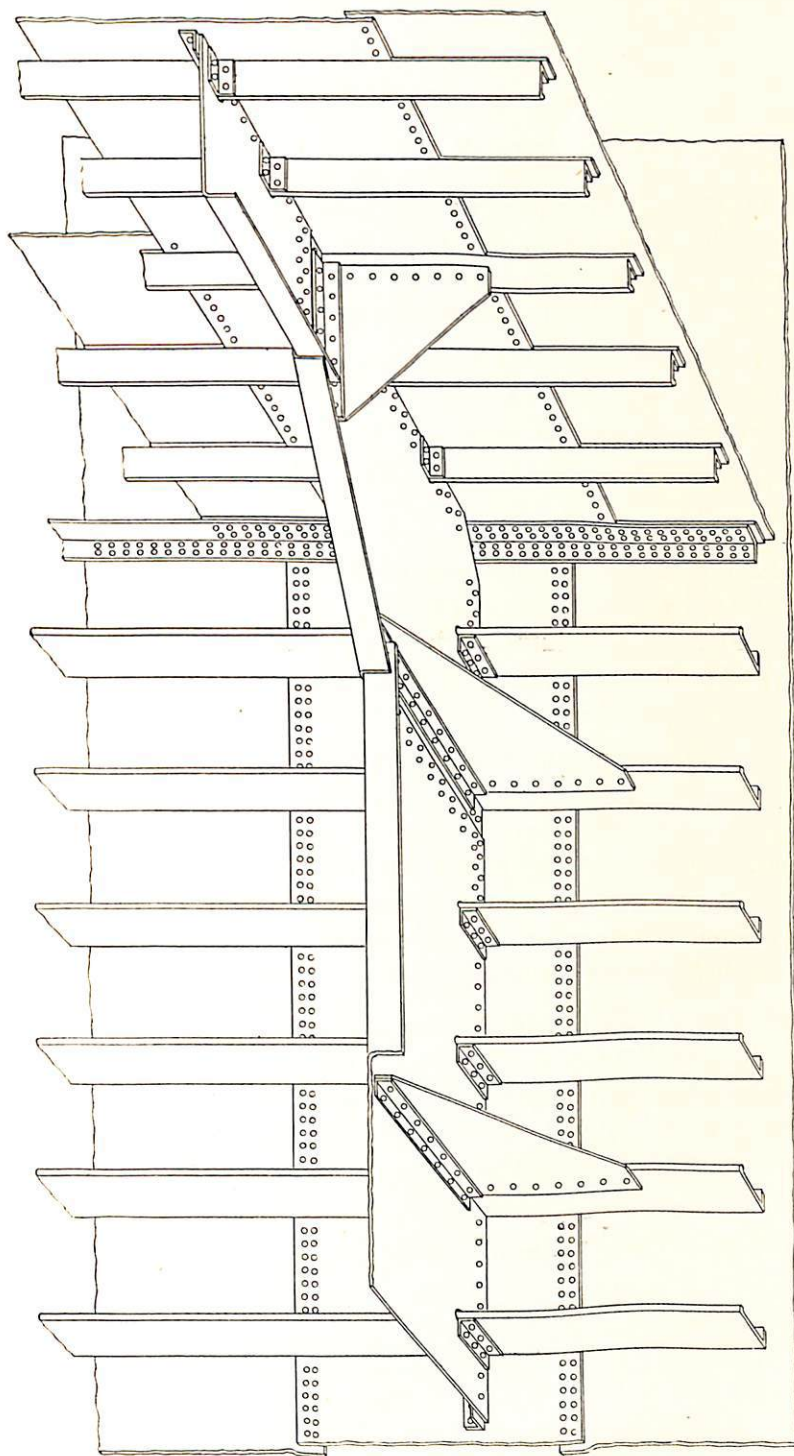
Deep Tanks Used as Oil Fuel Bunkers.—In this case, the ship's sides and the boundary bulkheads must have additional stiffening in the form of deep, horizontal girders, running right round the inside of the tank and spaced not more than 10 feet apart vertically. These girders must be stiffened by angles, bulb-angles, or flanges on their inner edges and are connected together at the tank corners by double-riveted, flanged brackets. They are supported at each third frame or stiffener by brackets and are attached to intermediate frames or stiffeners by angle lugs.

A middle line bulkhead must be fitted if the tank extends for the full breadth of the ship. This may be perforated if desired. Light intercostal stringers must be fitted horizontally across it, in line with the horizontal girders, if the latter are bracketed to it.

Quarterline girders must be fitted at the deckhead; these are often formed by deepening the ordinary deck girder.

Deep Tanks for Carrying Oil as Cargo.—Deep tanks may be used for the carriage of oil cargo, provided that its flash point does not exceed 150°F. In this case, the tank may be constructed in the same way as one built for oil fuel bunkers, except that a wash plate may be fitted in lieu of the centre line bulkhead.

Cofferdams.—Fuel oil, vegetable oil, or water, may not be carried in adjacent tanks, unless these are separated from each other by a cofferdam.



DEEP TANK FOR OIL FUEL.

PEAK TANKS AND PANTING ARRANGEMENTS.

Fore Peak Tanks.—The general arrangements for fore peak tanks are similar to those for deep tanks. They are not required to have heavy deck girders, however, but must have washplates at the centre line in all cases and must also be specially stiffened to resist panting.

Panting Arrangements in Fore Peaks.—Tiers of panting beams are fitted forward of the collision bulkhead, below the lowest deck. These are similar to ordinary deck beams and are connected to the frames by beam knees, but are only fitted at alternate frames. The tiers of beams are spaced 6 feet apart vertically.

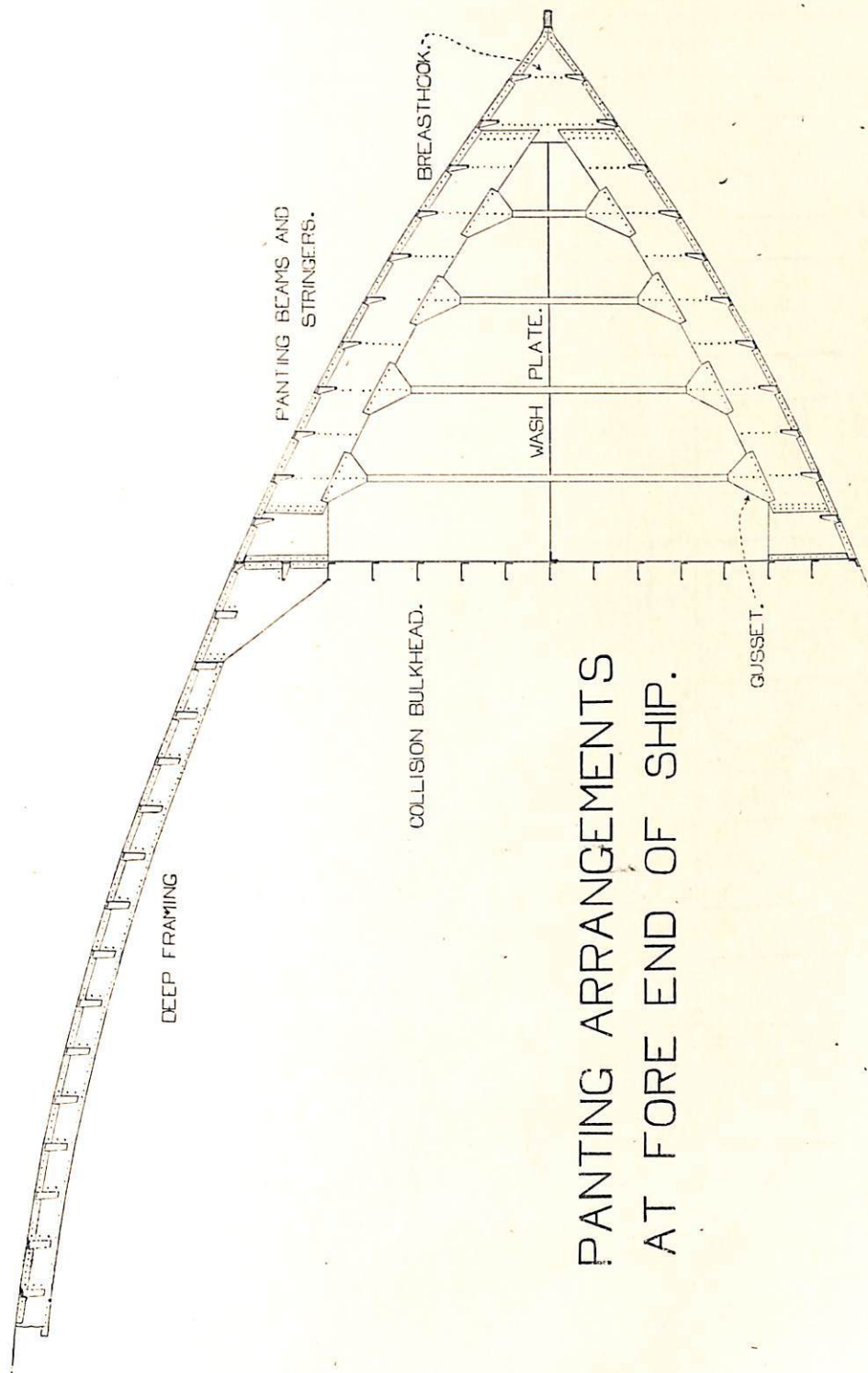
Panting stringers, similar to ordinary deck stringers, are laid on each tier of beams. They are usually attached to the shell plating by double angles and are connected together at their fore ends by flat plates, called "breast-hooks." At intermediate frames, where no beam is fitted, the frame is attached to the panting stringer by a beam knee of half the depth of the stringer plate.

Panting Arrangements Aft the Collision Bulkhead.—Deep framing, 20 per cent. stronger than normal, must be fitted below the lowest deck, between the collision bulkhead and a point 15 per cent. of the ship's length abaft the stem. Extra riveting is required in these frames and also in the tank side bracket connections. Side stringers must be fitted throughout the deep framing region. These must be in line with the panting stringers and are attached to the shell plating by single angles.

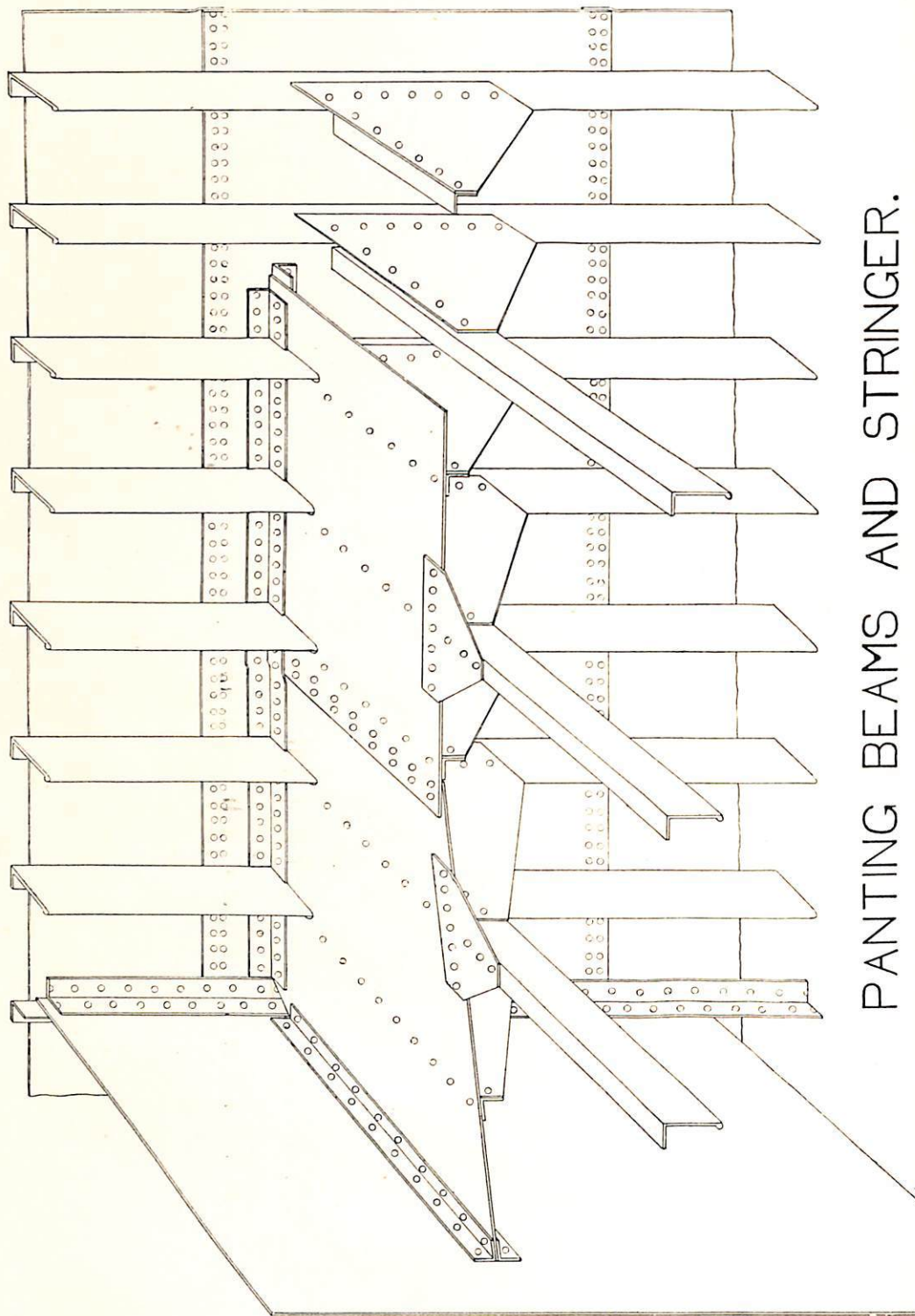
After Peak Tanks.—These are constructed in the same way as fore peak tanks, except that the tiers of panting beams may be 8 feet apart vertically. The plates joining the ends of the panting stringers are called "crutches" at this end of the ship. Deep floors must be fitted in the tank.

Deep framing, similar to that fitted forward, is not required at this end of the ship.

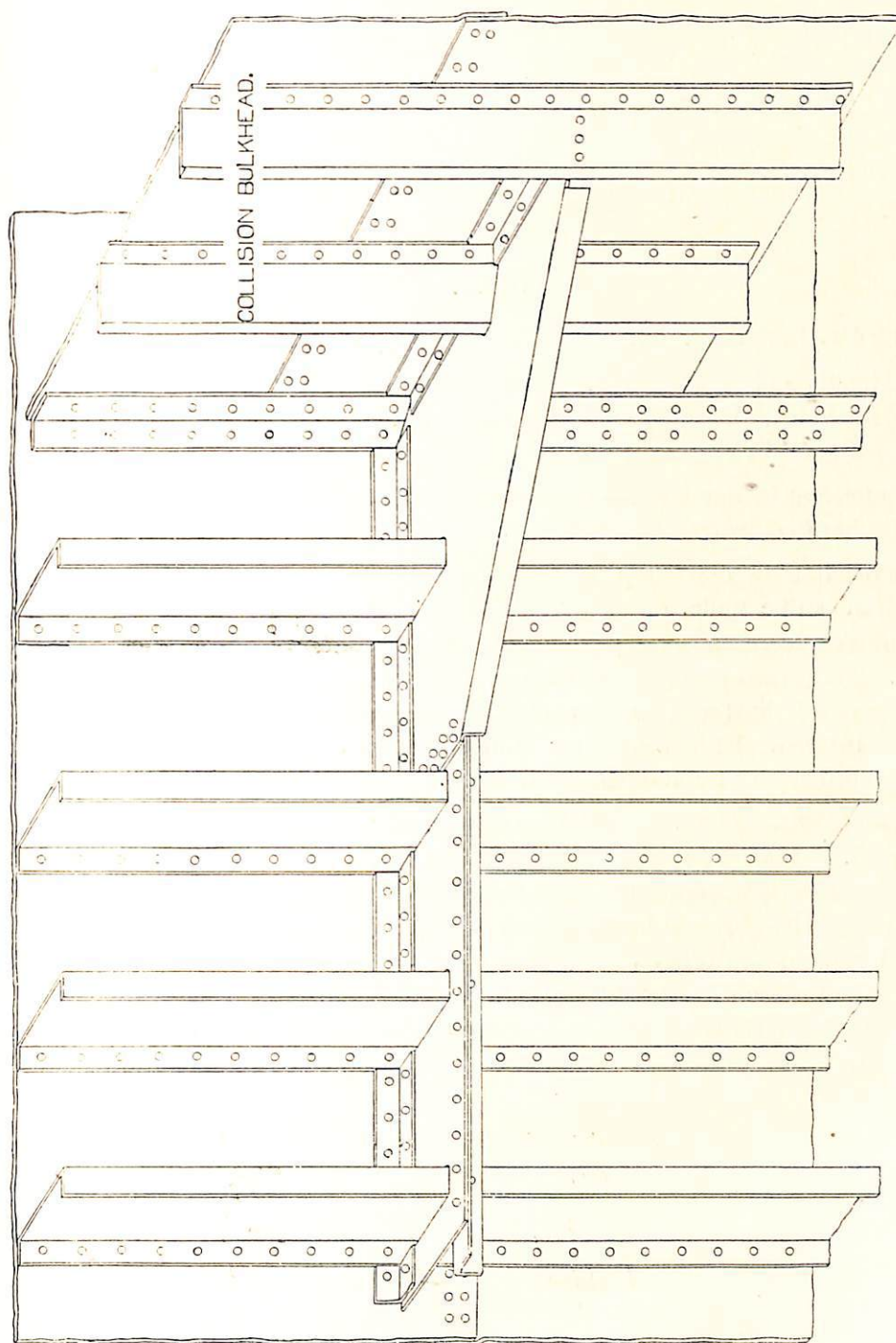
Tests.—The tests for peak tanks are the same as those required for deep tanks.



PANTING ARRANGEMENTS
AT FORE END OF SHIP.



PANNING BEAMS AND STRINGER.



DEEP FRAMING ABFT COLLISION BULKHEAD.

STEMS.

Lloyd's Dimension.—*L.*

Materials and Construction.—Stem bars are usually made of forged steel in modern ships. They are often made in two pieces, which are scarphed together about the light water line.

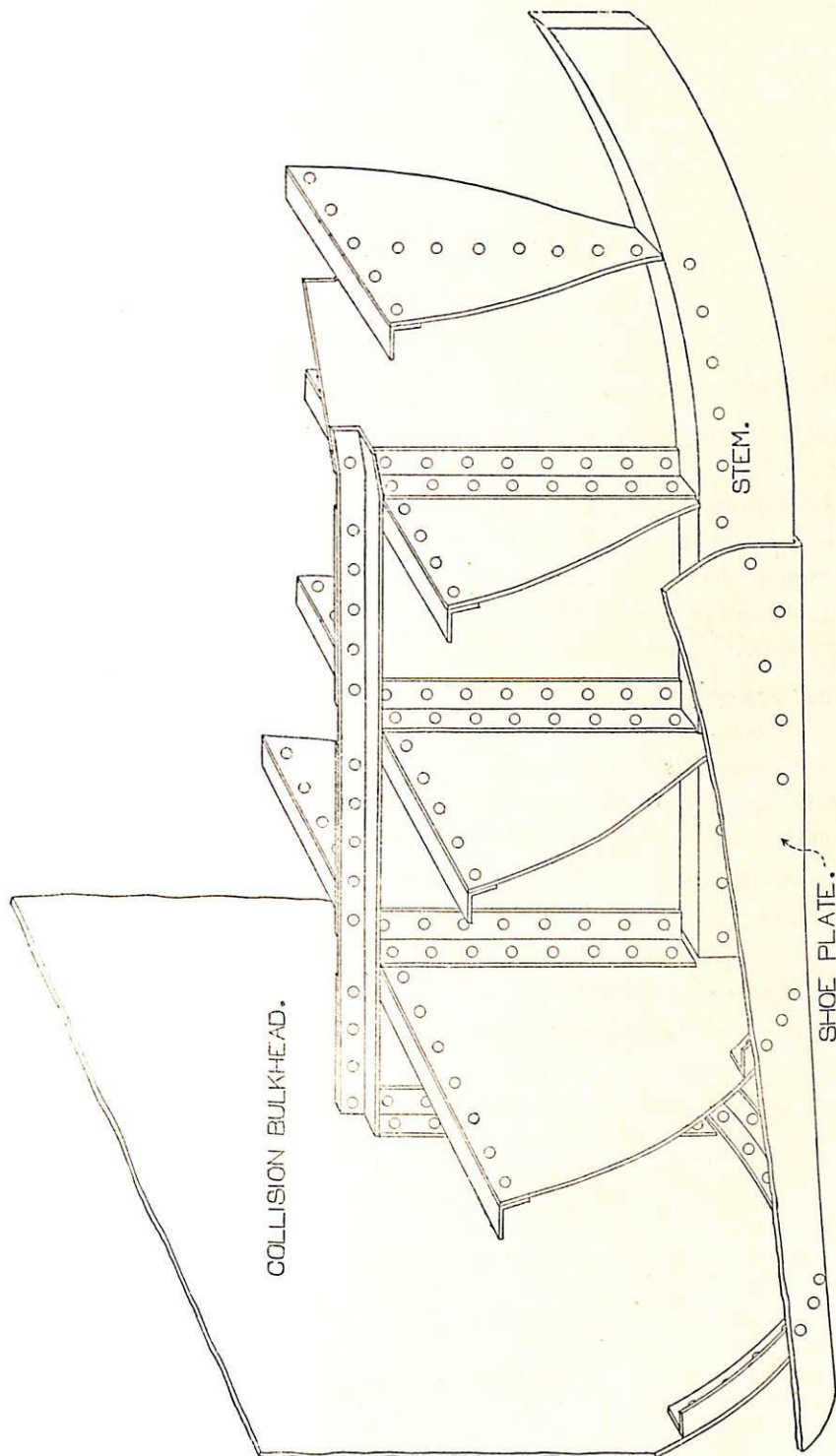
Connection to Bar Keel.—The stem is scarphed to and forms a continuation of a bar keel, where such is fitted.

Connection to Flat Plate Keel.—There are several ways in which this connection can be made.

One very common method is by means of a shoe plate, as shewn in the sketch. The forward end of the shoe plate is dished around the stem, whilst the after end is flattened to connect with the keel plate. The centre girder, which is intercostal forward of the collision bulkhead, is riveted to one side of the stem bar to complete the connection.

Plate Stems.—These are built up of curved plates, similar to plates “on the round.” Flat, horizontal plates, or “webs,” must be fitted inside the stem to reduce its unsupported span to not more than 5 feet. If the radius of curvature of the plates is large, it may also be necessary to fit some form of vertical centre-line stiffener.

The plated stem may continue right down to and form a continuation of the keel plate, or its lower part may consist of an ordinary stem bar.



ATTACHMENT OF STEM TO FLAT PLATE KEEL.

STERNFRAMES.

Lloyd's Dimension.—*L*.

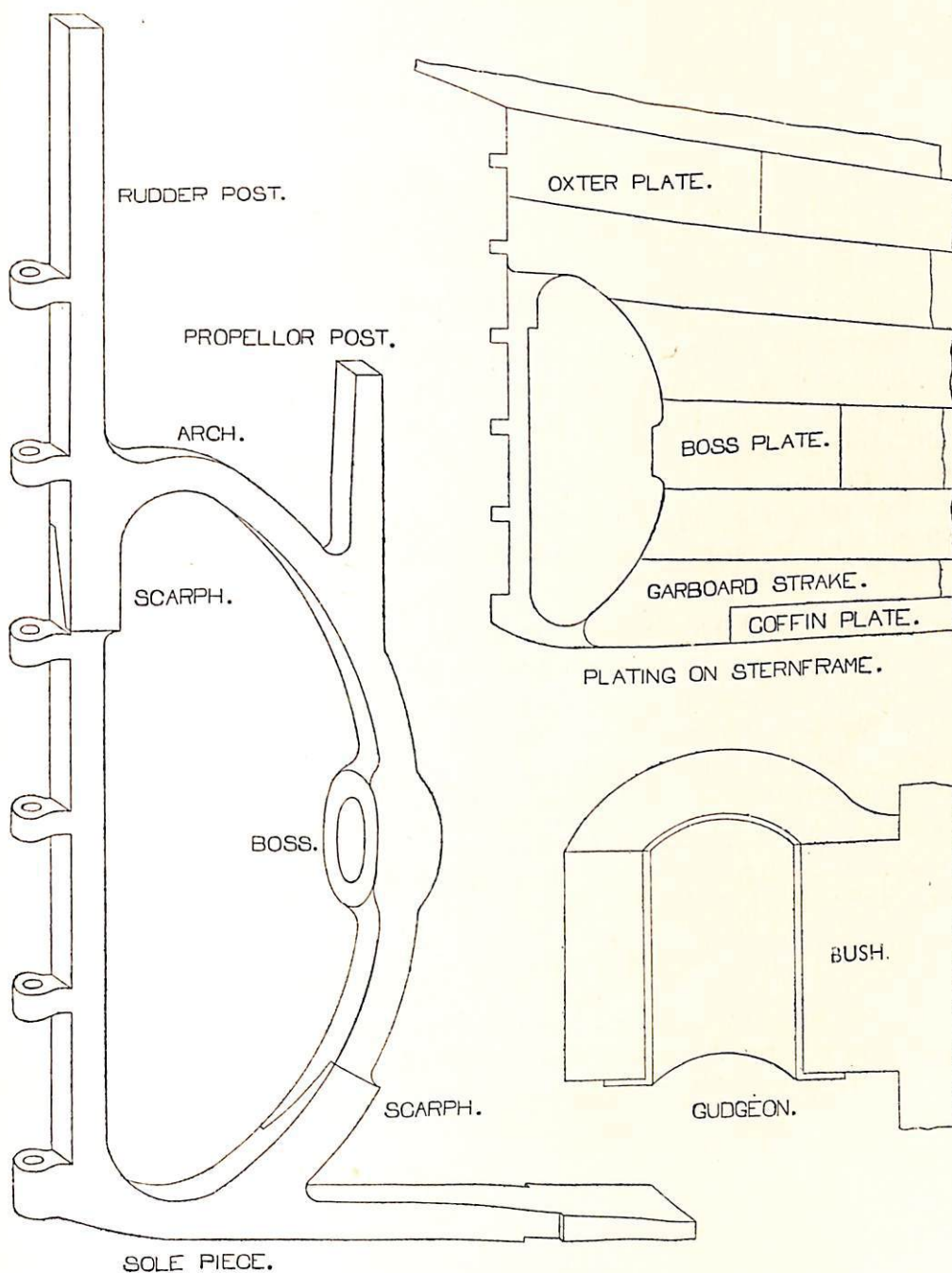
General.—Sternframes may be solid rectangular bars, or streamlined castings; or they may be built up of heavy plates, welded together.

Solid bars must have a fore and aft dimension of not less than $1\frac{1}{4}$ times their width, but not less than 5 inches in any case. Other types are to have a specified shape and thickness. The sole piece must be 50 per cent. wider than the rest of the sternframe, whilst its vertical depth must equal the width of the sternframe.

Scarphs.—Sternframes are usually made in two or more pieces, for convenience of construction and repair. The parts are connected together by scarphs, which must have a breadth of $1\frac{1}{2}$ times and a length of 3 times the fore and aft thickness of the sternframe. In single screw ships, the upper scarph should not be above the uppermost gudgeon.

Gudgeons.—Gudgeons are usually forged on to, or cast with the post. They must have the same depth as the pintles and a thickness of metal equal to 50 per cent. of the diameter of the pintles. Gudgeons often have bushes fitted inside them, to reduce wear.

Sternframes in Twin Screw Ships.—Modern twin screw ships do not usually have a propeller opening and the sternframe is a simple bar or casting. When it is a solid bar it must have a fore and aft dimension of 3 times its width.



STERNFRAMES.

STERNFRAMES—*(Continued).*

Connections at Head.—The rudder post extends upwards to the top of the transom floor, to which it is connected by double angles. If the length of the ship exceeds 300 feet, these angles are to be double riveted. Cast stern frames usually have flanges cast on the post to serve the same purpose as the double angles.

In single screw ships which have cruiser sterns and in all ships of over 300 feet long, the propeller post is extended above the arch and connected to a deep floor.

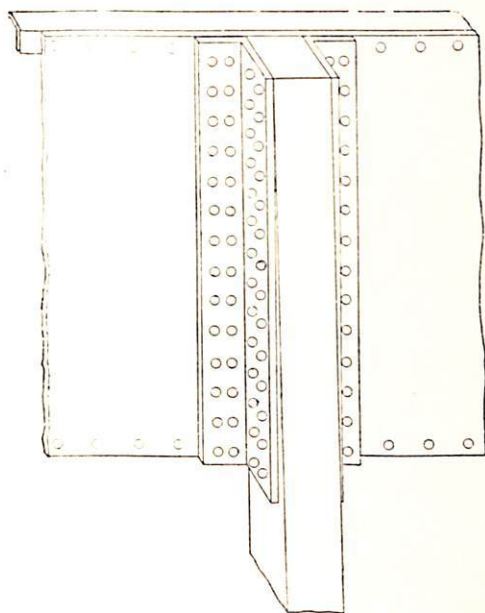
Connections at Bottom.—The sternframe must extend forward far enough to provide an efficient connection with the flat plate keel: usually for two or three frame spaces. It is usually flattened out so that the aftermost keel plate can be dished around it in a box-like form. This plate is called the "coffin plate." The sternframe is often notched, as shewn in the sketch, to give a neat connection to the coffin plate and garboard strakes.

Transom Floor.—This is the floor above the rudder post, to which the framing of the stern is attached. It must have the same depth as the floors in the cellular double bottom.

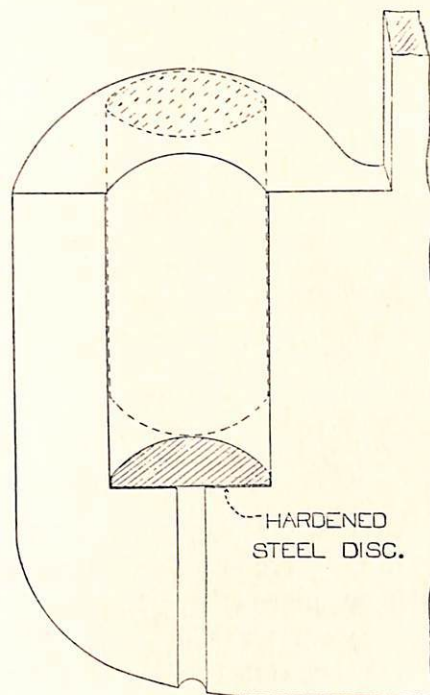
Riveting.—Four rows of rivets must be used in the scarphs of the stern-frame.

Connection to the shell plating is by two rows of rivets, generally; but three rows are used below the boss in ships of over 350 feet length.

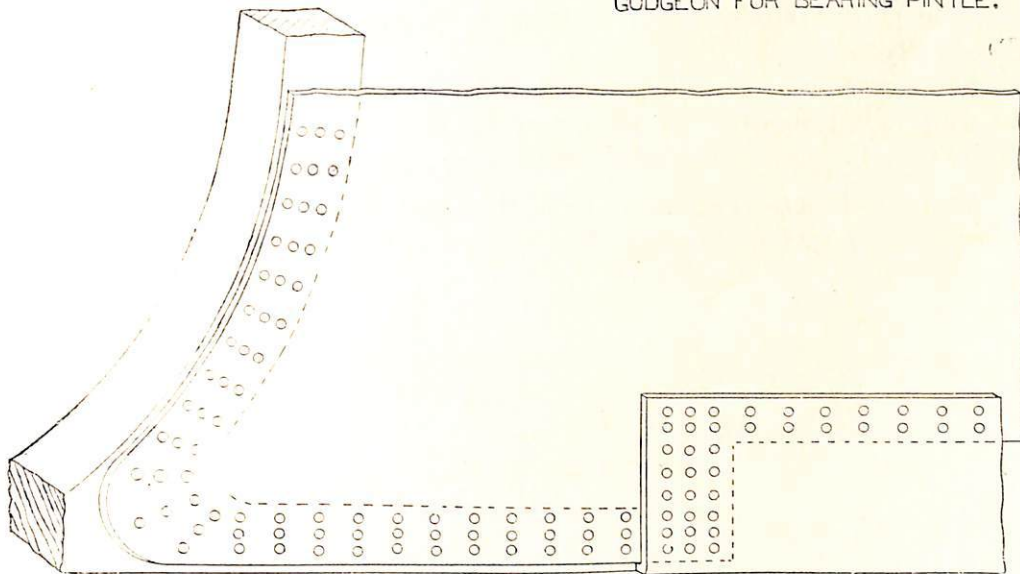
The pitch of riveting is generally 5 diameters.



CONNECTION TO TRANSOM FLOOR.



GUDGEON FOR BEARING PINTLE.



CONNECTION TO KEEL.

STERNFRAMES.

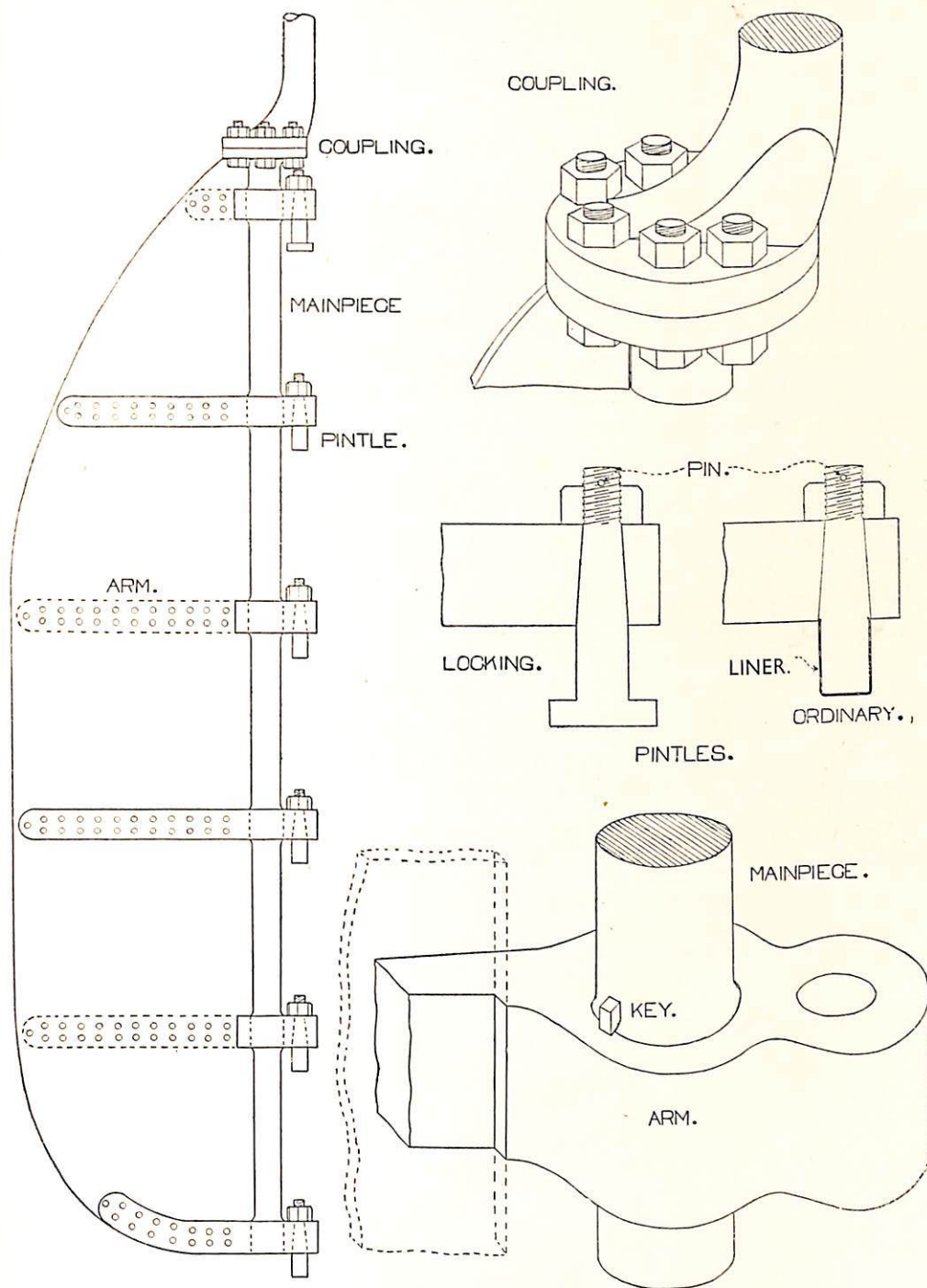
ORDINARY STERNS.

General.—These are sometimes called “Elliptical Sterns.” The upper part of the stern of a ship extends abaft the rudder post, and there must be a special arrangement of framing to support it. In the ordinary stern the necessary support is obtained by fitting a “Transom ” and “ Cant Frames.”

The transom consists of a deep, heavy floor, securely attached to the rudder post, in association with a transverse frame and beam. These are known as the “ Transom Floor,” “ Transom Frame ” and “ Transom Beam ” respectively.

The cant frames are attached to the transom floor by brackets and radiate out from it in somewhat the same way as the spokes of a wheel. The fore ends of their beams are attached to the transom beam.

Transom Floor.—This must have the same depth as the floors in the cellular double bottom, but must be slightly thicker.



SINGLE PLATE RUDDER.

CRUISER STERNS.

General.—Cruiser sterns are not framed in the same way as ordinary sterns, but are more or less a continuation of the main part of the hull. They extend to below the load water line, but above the light water line.

A system of ordinary transverse framing is fitted, which is supported by an intercostal girder at the centre line. This girder is, in its turn, strongly attached to the transom floor. A number of "cant frames" are fitted abaft the aftermost transverse frame.

Frames.—The frames are to be of the same size as bulb angle frames in peaks and are to extend to the strength deck. The frame spacing is to be 24 inches.

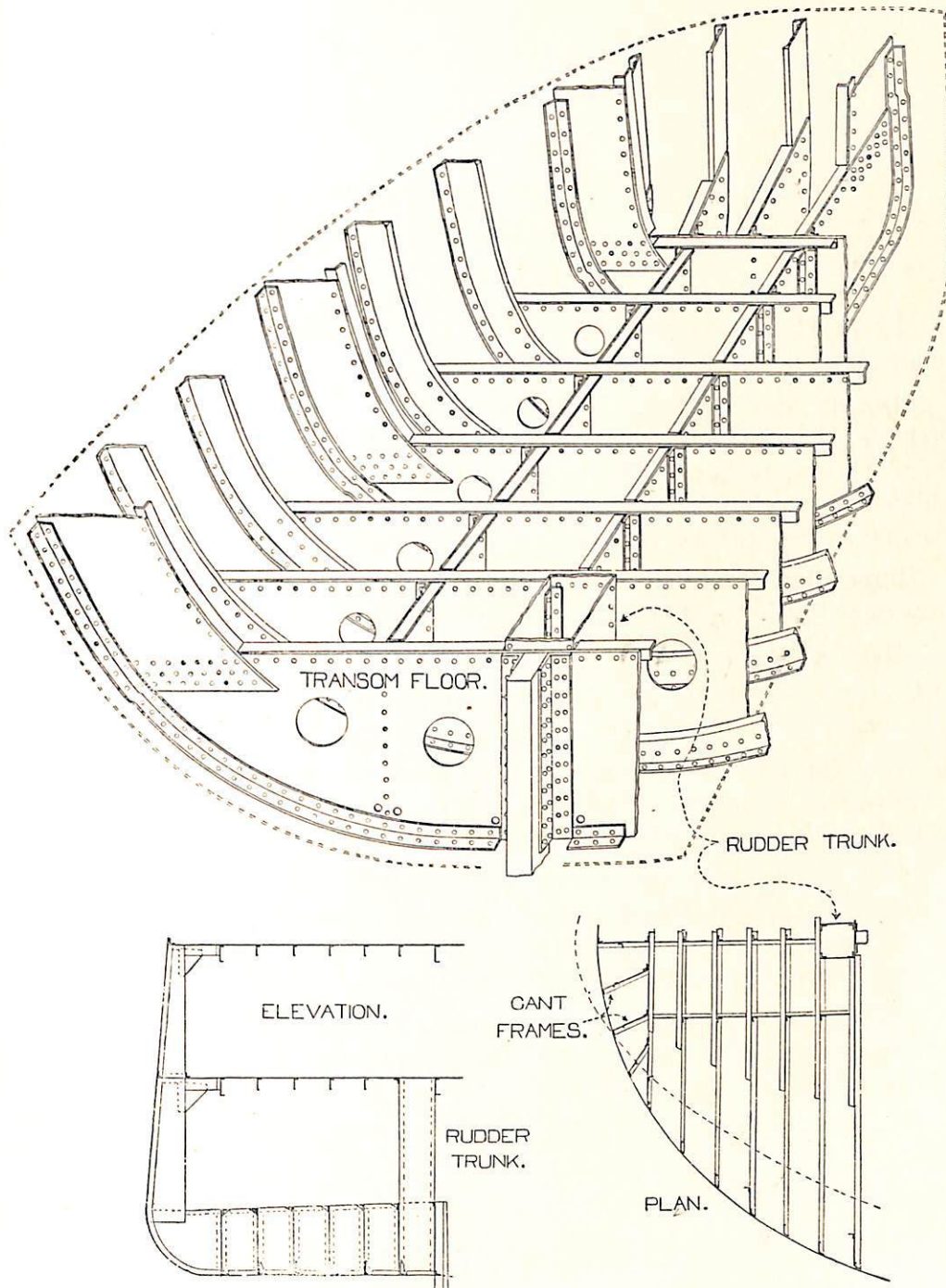
Where extra strength is required, web frames may be required and also extra longitudinal girders to support them.

Floors.—Floors are to be of reasonable depth.

Beams.—The size of beams is to be as for the other beams in the ship.

Shell Plating.—Shell plating in the way of cruiser sterns is normal for the ends of the ship.

Rudder Trunk.—This is often formed by doubling the centre girder between the first two floors and carrying it up to the deck above in the form of a box. (See sketch.)



CRUISER STERN.

RUDDERS.

Single Plate Rudders.—The ordinary type of rudder usually consists of a single plate with arms riveted on either side of it.

Double Plate Rudders.—These are similar to single plate rudders, except that they have two plates with the arms between them. The space between the plates may be filled with wood or cement : more often it is left empty, in which case the inside surfaces are given some protective coating, whilst means must be provided for draining the rudder.

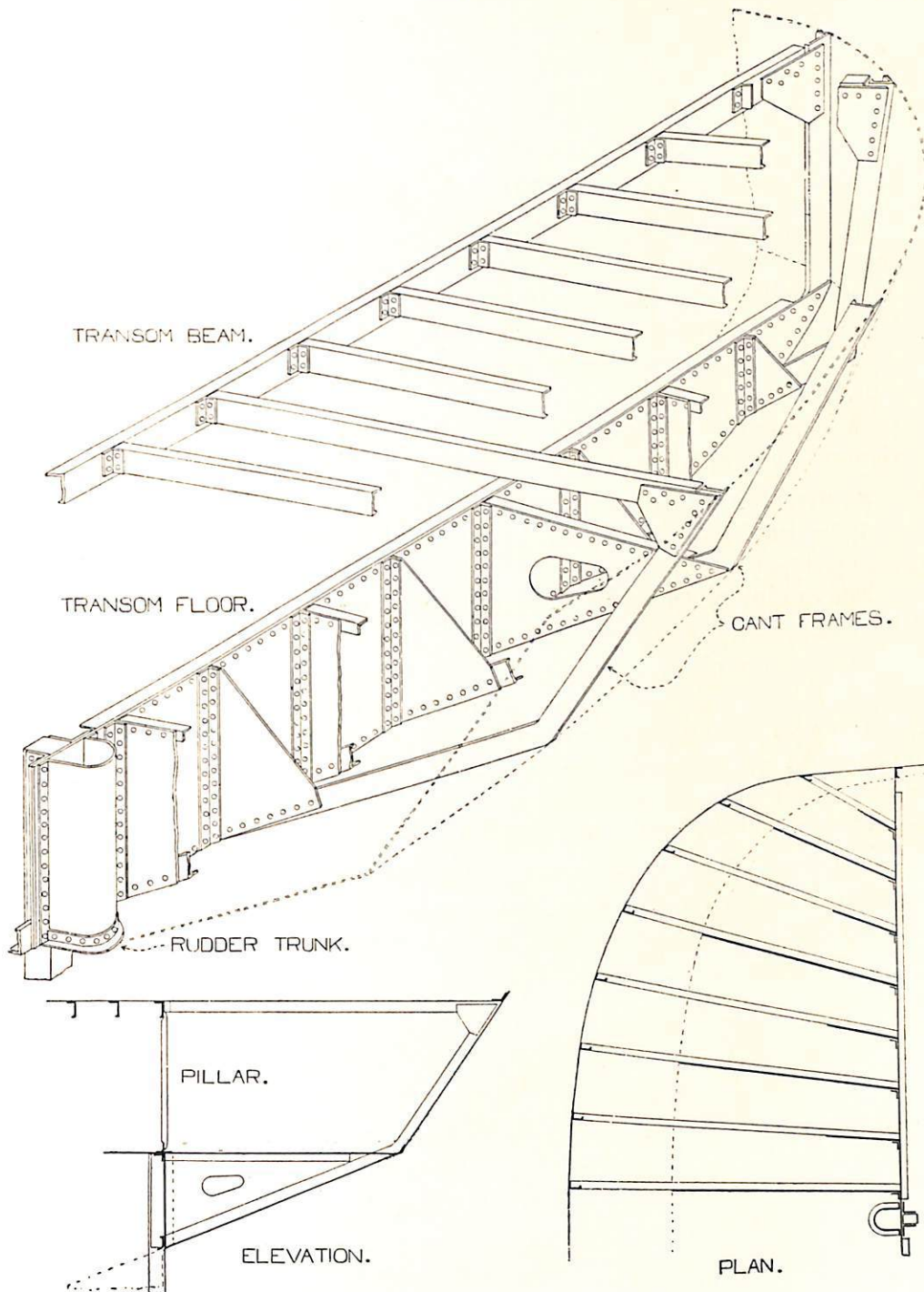
Streamlined Rudders.—Many modern rudders of the double plate type are streamlined ; that is, the plates are curved to reduce resistance.

Balanced Rudders.—Balanced rudders are now very common, particularly in twin-screw ships with cruiser sterns. They have about one-third of their area forward of the main piece, in order to reduce the thrust on the rudder.

Bow Rudders.—Some ships, such as Cross-Channel vessels, have a rudder fitted in the bow, inside the line of the stem. They are used for steering when the ship is going astern, and are worked by hand from the fore deck.

Size.—The sizes of the various parts of a rudder depend on the diameter of the rudder head. This in its turn depends on the speed of the ship, the area of rudder abaft the fore edge of the mainpiece and the distance of the centre of gravity of the rudder abaft the pintles.

Mainpiece.—The diameter of the mainpiece at the top pintle must be the same as that of the rudder head. It may be reduced gradually in size from this point towards the heel.



ORDINARY STERN.

RUDDERS—(Continued).

Arms.—In single plate rudders, these are usually shrunk on to the mainpiece and kept from turning by means of a key. In this case, the thickness of the mainpiece is increased by 10 per cent. in the way of the arms, which are fitted on alternate sides of the rudder plate.

In double plate rudders, the arms are usually cast with, or forged on to the mainpiece.

In streamlined rudders, the arms and mainpiece are often built up of horizontal and vertical web-plates, shaped as required.

Pintles.—Pintles are the “hinges” on which the rudder turns. They are sometimes lined to reduce wear. Their depth must be the same as that of the gudgeons.

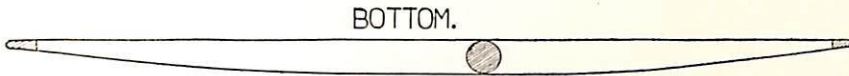
The locking pintle, which is usually the uppermost one, has a head on it, below the gudgeon, to prevent the rudder from lifting.

The bearing pintle is usually the lowest one and takes the weight of the rudder. A hardened steel disc is often placed in the bottom of the gudgeon to take the wear and a vertical hole in the bottom of the gudgeon allows it to be punched out and renewed. Bearing pintles are not fitted in balanced rudders, as here the weight of the rudder is taken by a special arrangement at the rudder head and the pintles merely act as pivots.

Couplings.—The rudder stock is connected to the rudder by either a horizontal coupling or by a vertical scarph. The bolts through these must be locked by means of pins or some similar arrangement.

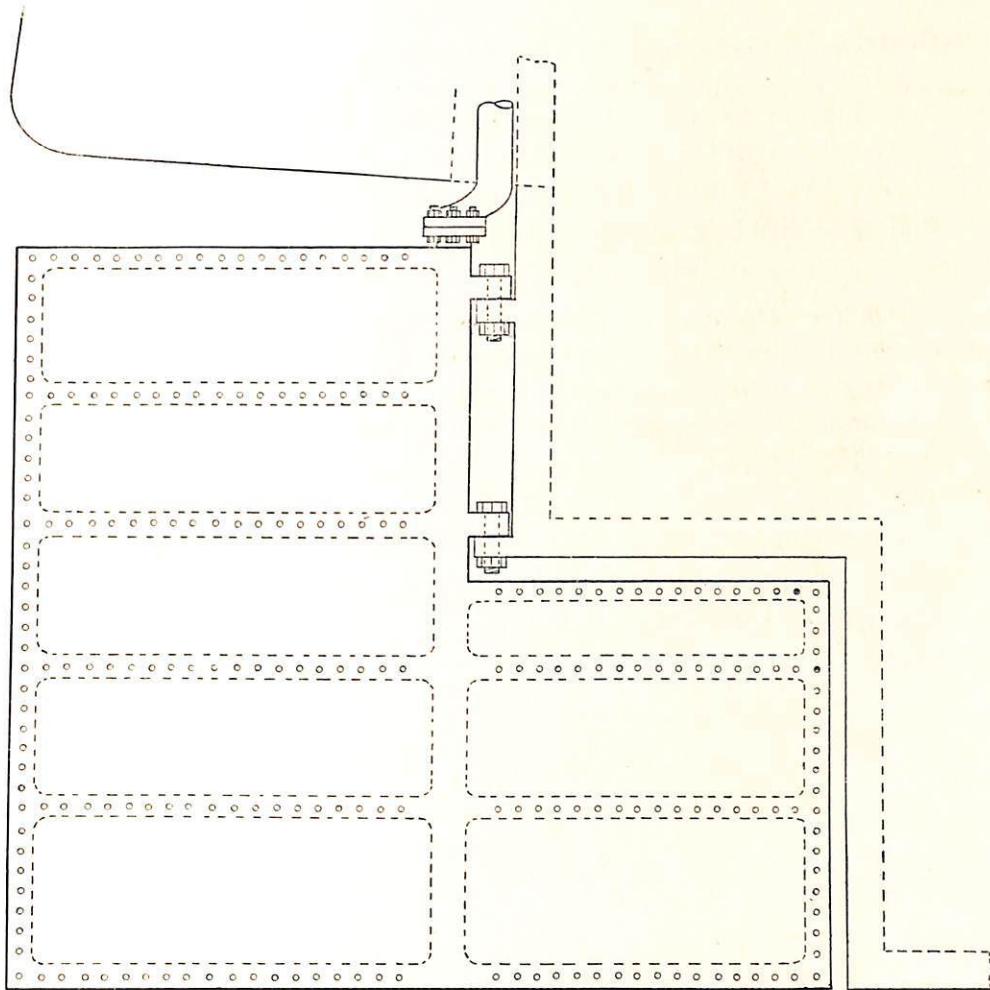


TOP.



BOTTOM.

PLANS.



BALANCED RUDDER.

SHAFT TUNNELS.

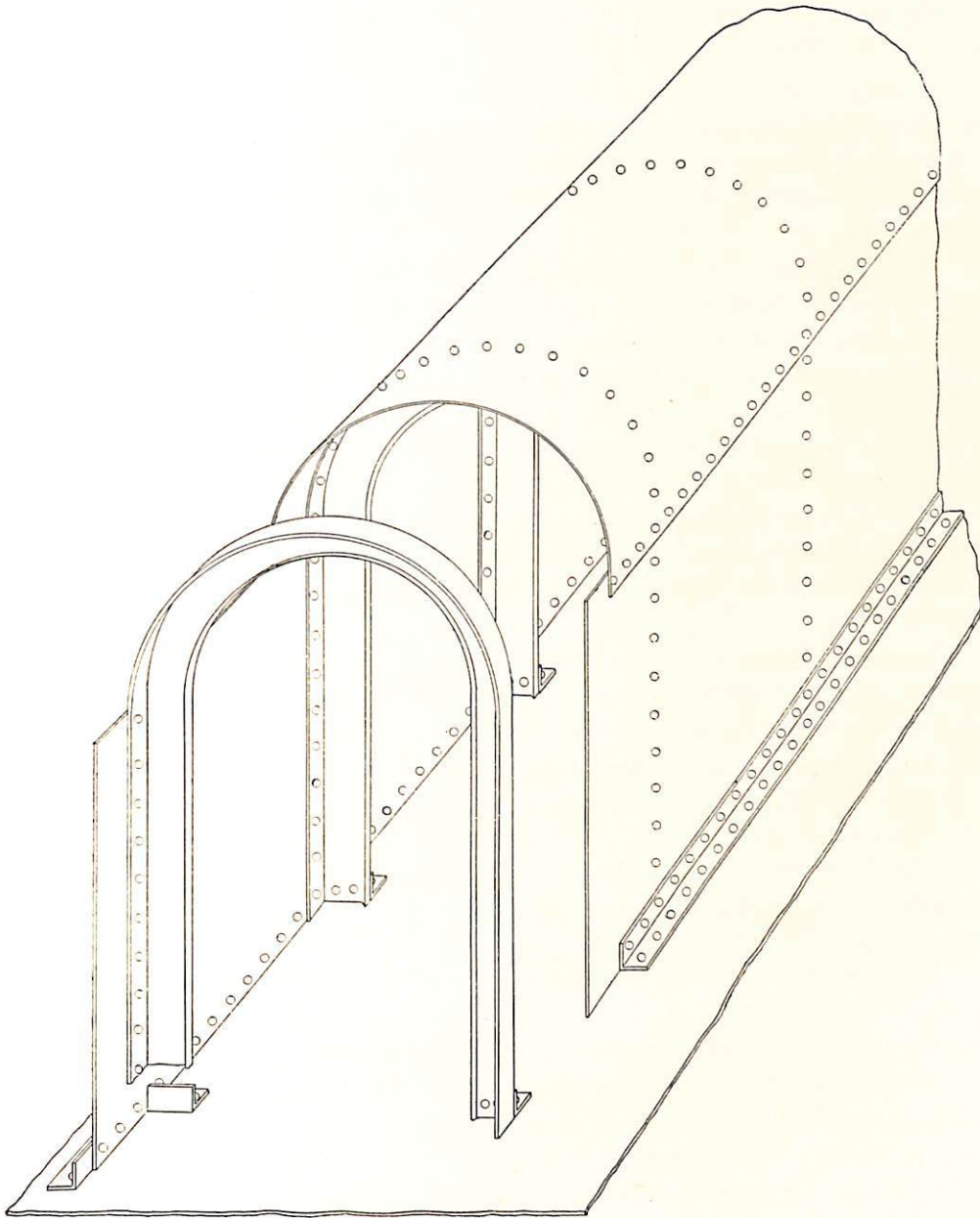
General.—Shaft tunnels are fitted in order that the propeller shaft may be accessible at all times. They also prevent water from filling the holds if the stern tube be broken. In twin screw ships two shaft tunnels may be fitted, but more often the whole width of the ship is decked over and the space between the shafts used for workshops, etc.

Plating.—Must be thickened slightly in the way of hatches to guard against damage when cargo is being worked.

Stiffeners.—The size of the stiffeners depends on the height of the tunnel and its depth below the bulkhead deck. They may consist of angles, or bulb angles. Angle stiffeners of over 6 inches deep and all bulb angle stiffeners are to be connected to the inner bottom by angle lugs. The standard spacing of stiffeners is 36 inches.

Tunnels Passing Through Deep Tanks.—When tunnels pass through deep tanks, the spacing of the stiffeners is to be the same as for bulkheads and they are to be bracketed to the inner bottom.

Watertight Doors.—Watertight doors are to be fitted at the engine room bulkheads.



SHAFT TUNNEL.

STERN TUBES AND PROPELLERS.

General.—The purposes of the stern tube are to support the shaft and to make a watertight joint where the shaft enters the hull.

Fitting.—At the fore end of the tube there is a flange which is bolted to the after peak bulkhead. At its after end the tube has a small flange cast on it and abaft this it is threaded to take a large nut. When it is in position, the flange bears against the fore side of the sternframe and the nut on the after side.

Construction.—The tube itself is usually made of cast iron. Inside this again is a brass bush which has grooves in it, running fore and aft. Strips of lignum vitae are fitted into these grooves to act as a bearing for the shaft. The strips are kept in place by means of a ring known as the "check ring," which is bolted on to the after end of the tube.

Small spaces are left between the lignum vitae strips and through these the water can enter to lubricate and cool the shaft. In order to prevent this water from getting into the hull of the ship, a stuffing box is fitted at the fore end of the stern tube. The aftermost length of shafting, which revolves in the stern tube, is known as the "Tail End Shaft." It usually has a brass liner shrunk on to it.

In some ships the stern tube is bushed with white metal instead of lignum vitae and oil is used for lubrication. In this case special glands are used to prevent the escape of oil.

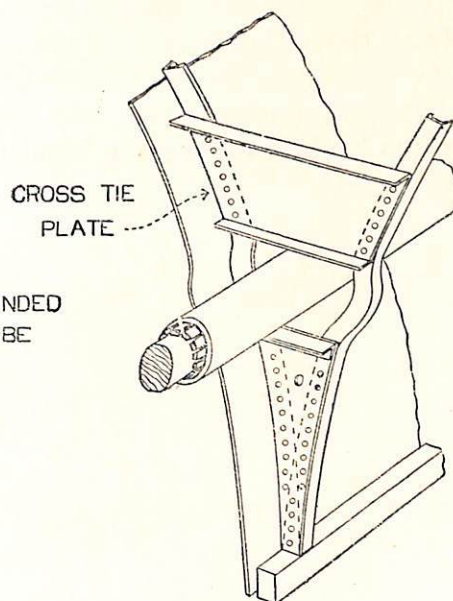
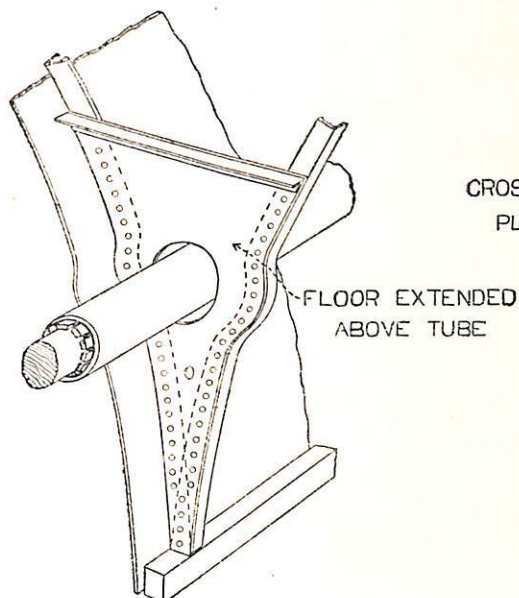
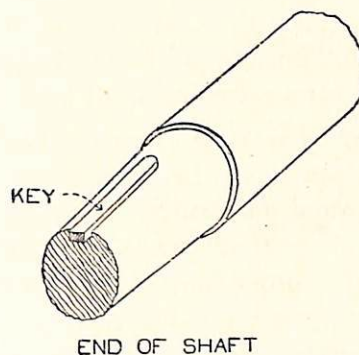
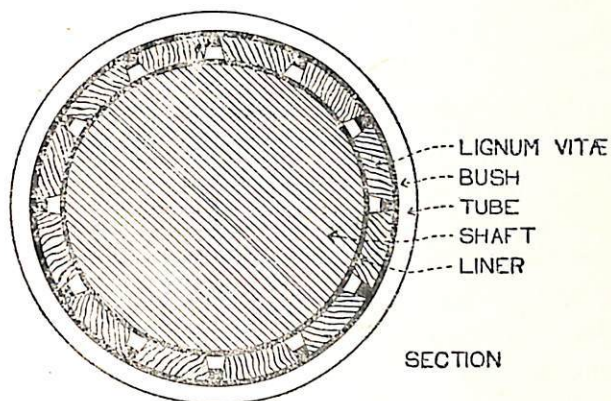
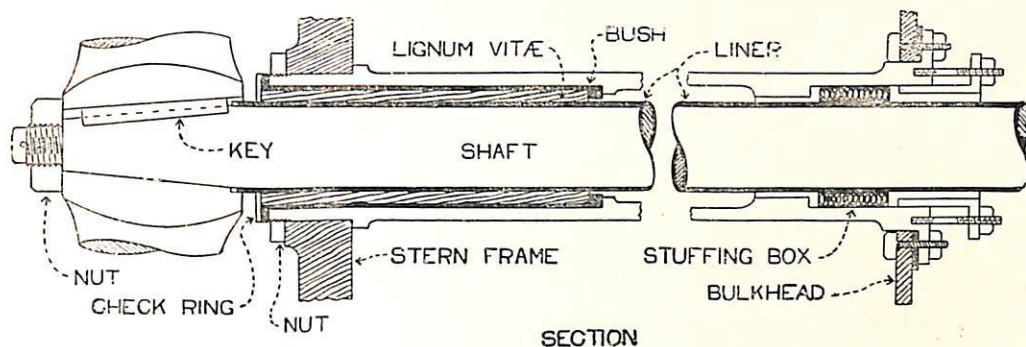
Strengthening Around Stern Tube.—There is usually considerable vibration in the vicinity of the stern tube, and arrangements must be made to strengthen the ship against this.

The floors must extend above the tube. If this is impossible, deep "cross tie plates," flanged on their upper and lower edges, must be fitted above the tube.

The plating of the after peak bulkhead must be thickened or doubled around the tube. The shell plating must also be thickened in this vicinity and the pitch of riveting must not be more than 5 diameters.

Propellers.—Propellers may be cast in one solid piece or they may consist of a boss with the blades bolted on to it. The holes for the heads of the bolts are usually filled in with cement.

The tail end shaft is tapered at its after end to take the propeller. The latter is kept from turning on the shaft by means of a key which is inserted in a key way on the shaft before the propeller is put on. A large nut is put on the after end of the shaft to prevent the propeller from coming off. To prevent this nut from coming undone it is always made left-handed for a right-handed propeller, and it is further secured by means of a pin or some similar locking device.



STERN TUBES.

TWIN SCREWS.

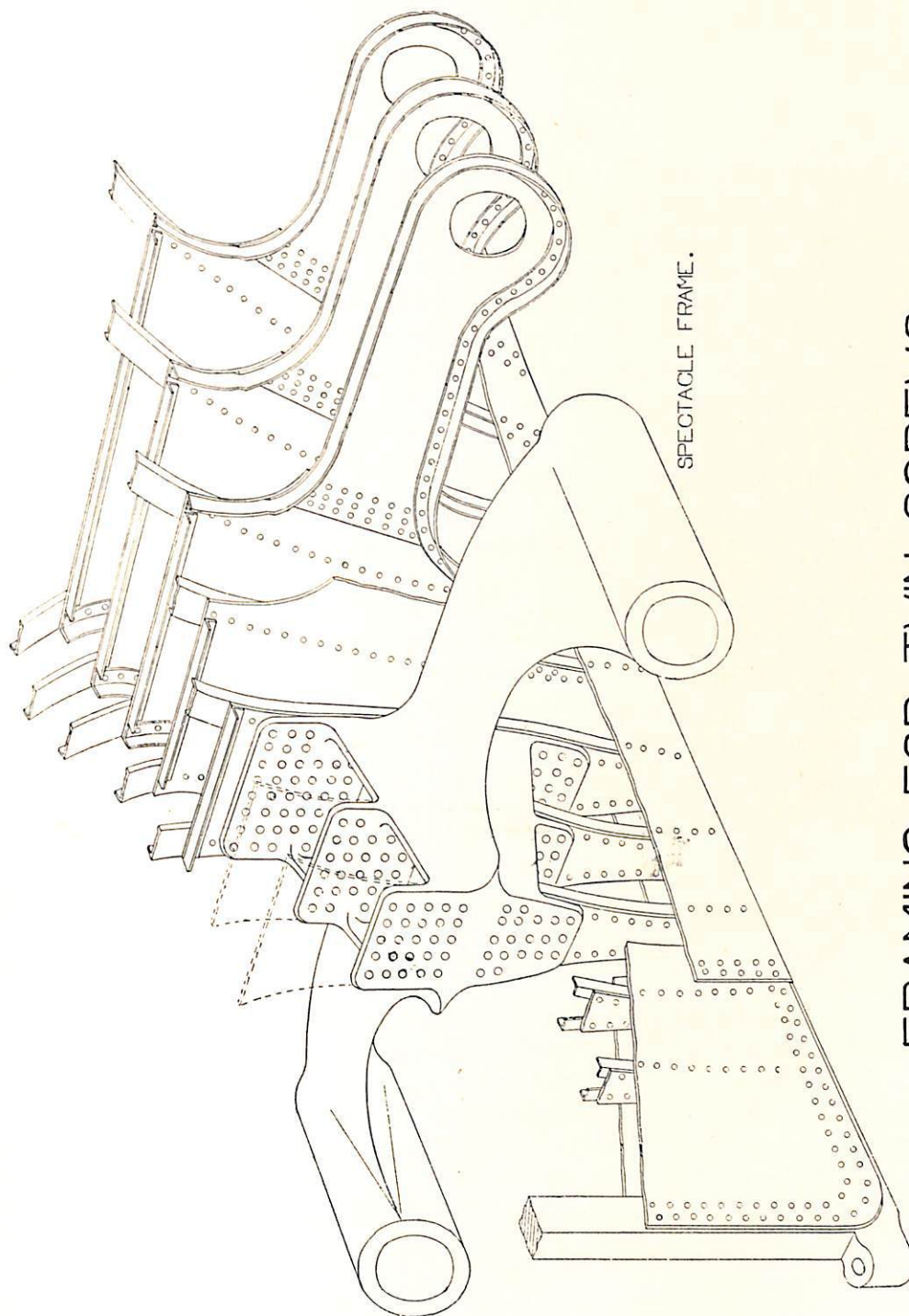
General.—In a hull built for twin screws, special arrangements must be made to support the shafts and to avoid weakness.

In older ships the shafts were often made to leave the hull at a point some distance forward of the propeller and were supported at their after ends by brackets known as "A Brackets." In modern practice, it is usual to keep the shafts inside the hull for their whole length and to "boss" the hull out around them. In this case, the after end of the shafts is supported by a strong casting built into the hull and called a "Spectacle Frame."

Spectacle Frames.—In older ships, the tips of the propellers often overlapped. In this case, the stern frame had a small aperture and the spectacle frame was usually bolted on to the propeller post.

In modern ships the screws are usually further apart, and the sternframe is a simple bar with no aperture. The spectacle frame is fitted forward of the sternpost, and is a casting of such a shape that it can be strongly connected to several specially strengthened floors and to the shell plating.

Bossing.—This is the name given to the bulging out of the floors around twin screws. At the fore end, where there is only a small swelling, the main floors and frames are shaped to the required form. Further aft, where the swelling is greater, the main floors and frames are not interrupted. They maintain their original form, and have separate plates and angle frames riveted on to them to form the bossing.



FRAMING FOR TWIN SCREWS.

HATCH COAMINGS.

General.—The resistance to longitudinal stress is much reduced in the way of hatches, on account of the large amount of material which must be cut out of the deck. This causes a tendency for the deck to fracture at the hatch corners. There is also a loss of resistance to loads of water or cargo on the deck, due to the beams being cut at the hatch coaming.

Both the above must be compensated for or the weakness might be dangerous. To give the necessary strength the deck plating must be strengthened or doubled, and the coamings and their connections must be sufficiently strong and rigid.

Height.—The height of coamings on upper decks, which are exposed to the weather, must be 24 inches. This may be reduced to 18 inches abaft one quarter of the ship's length from the stem on decks of superstructures, and on raised quarter decks.

The height may be 18 inches on decks inside superstructures which have no means of closing. It may be 9 inches inside superstructures having strong means of closing, such as wooden doors.

On decks within intact superstructures and on decks below the upper deck, the coamings may consist of angles only.

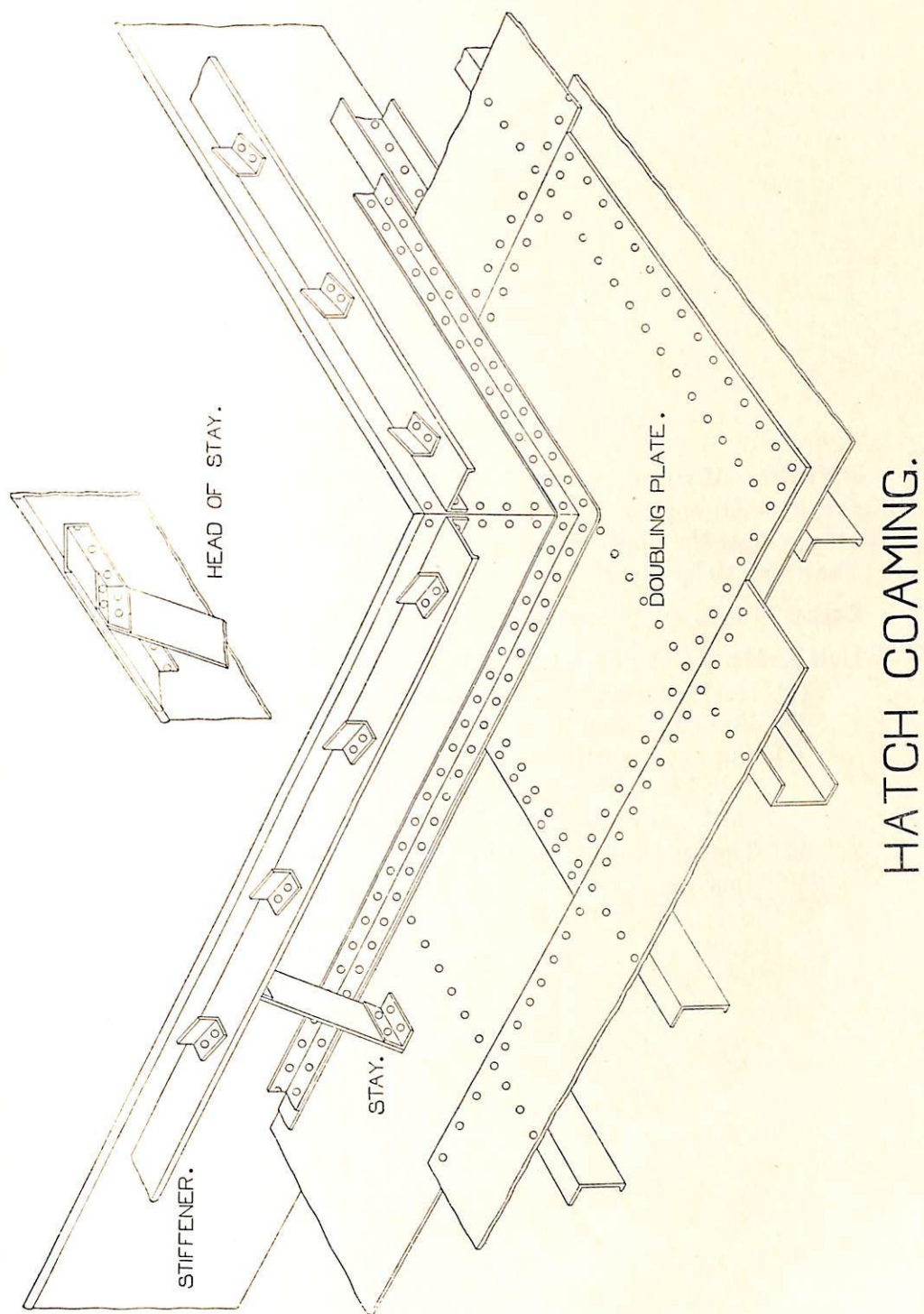
Connections.—The connection to the deck must be by an angle having the same thickness as the coaming. This angle must be caulked and must be made watertight at the hatch corners, by either bending it around the corner or by welding it.

The side coamings must extend to below the beams, to which they must be connected. (See "Beams.") The end coamings are usually riveted to the hatch-end beams.

When the hatch coaming is supported by the hatch end beams, horizontal gussets must be fitted to connect the side coamings to the hatch end beams.

At weather decks, deep hatch coamings should, if possible, be extended beyond the hatch ends as brackets: if this is not possible, girders should be fitted below the deck so as to extend the coamings for two frame spaces beyond the hatch ends.

At lower decks, coamings which do not form part of a deck girder, should be extended beyond the hatch ends by girders below the deck, as above.



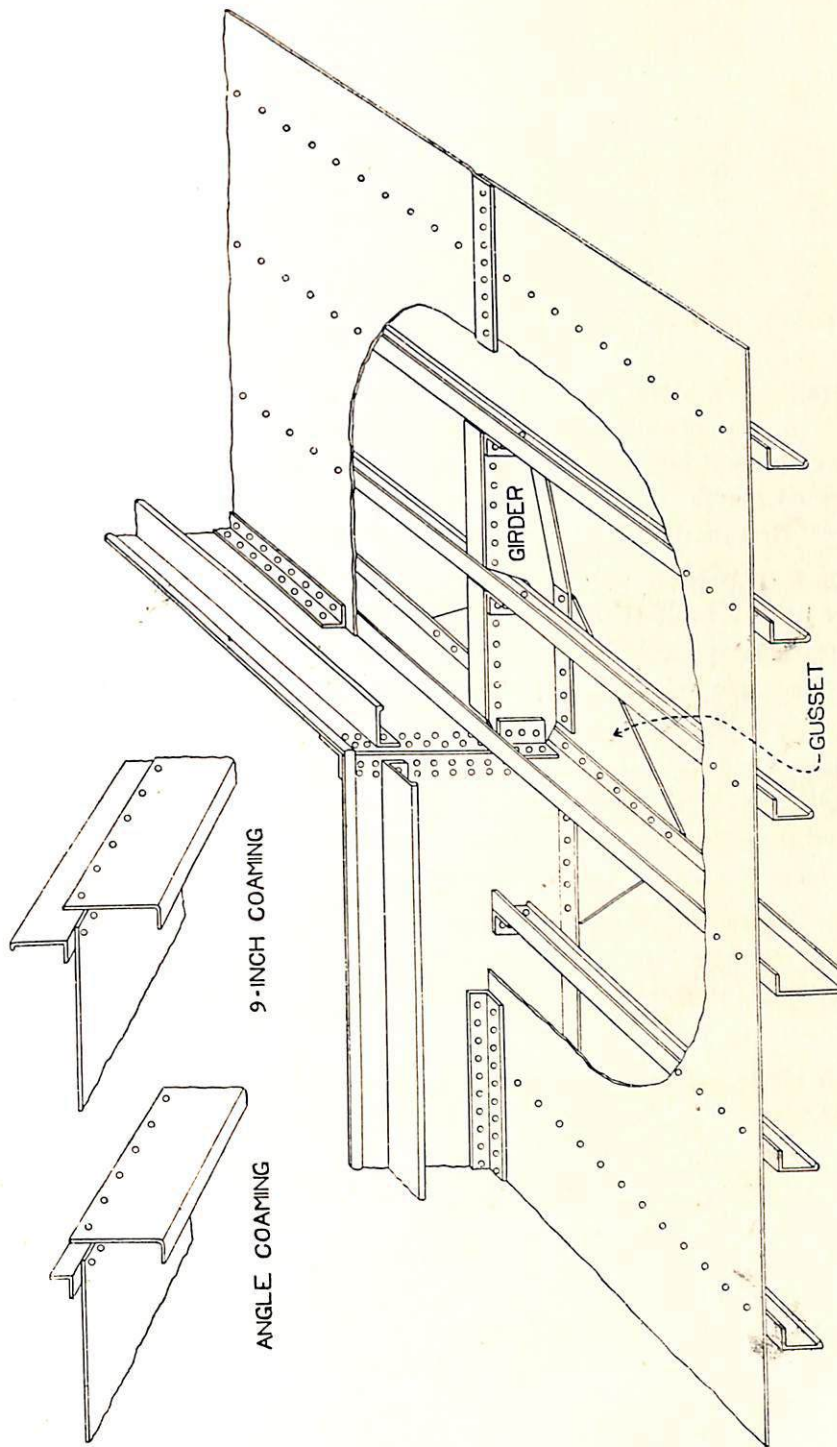
HATCH COAMINGS—*(Continued).*

Stiffeners.—If coamings are 24 inches or more in depth they are to be stiffened by bulb angles. These must be at least 7 inches deep and fitted horizontally near the upper edge of the coaming. Vertical stays or brackets are to be fitted, 10 feet apart, between the deck and the horizontal stiffener.

Decks.—Decks are to be doubled at the hatch corners.

Hold Ladders.—The Factory and Workshops Acts require that :—

- (a) Hold ladders shall all be in the same straight line.
- (b) Footholds shall be at least $4\frac{1}{2}$ inches deep and 10 inches wide.
- (c) Cups or cleats in coamings shall give the above foothold. They shall be vertically over each other and must be so constructed as to prevent a man's foot from slipping over the side.
- (d) The ladders shall not be recessed under the deck more than is necessary.



HATCH COAMINGS.

HATCH BEAMS AND COVERS.

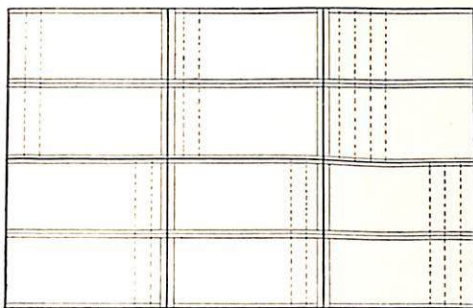
General.—A system of athwartships beams only, with fore and aft hatches, is nearly always fitted in modern ships. In some old ships, the hatches were sometimes placed athwartships and supported by fore and aft beams, called “fore and afters.” Steel hatch covers of various types, are sometimes fitted in the latest ships and have many advantages.

Beams.—The size of hatch beams is governed by their length and spacing. They may be of a built H-section, or a deep built T-section. The ends which rest in the carriers must have doubling plates, at least 7 inches wide. The depth of the beam at its end must not be less than half of its depth at the middle, nor less than 6 inches in any case.

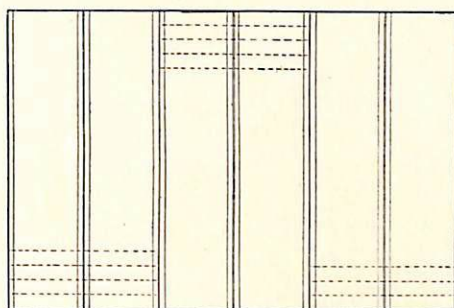
Carriers.—The sockets in which the ends of the beams rest are called “carriers.” When they are of the type shewn in the sketch, their bottoms must be solid and one of the angles must extend down the coaming to deck level. At least 3 inches of the beam must bear on the carrier.

Hatch Covers.—Wooden hatch covers must be $2\frac{3}{8}$ inch thick when their unsupported span is 5 feet, $3\frac{1}{4}$ inches thick for a span of 6 feet 6 inches, or intermediate for intermediate spans. Their ends must be fitted with galvanised steel bands, about $2\frac{1}{2}$ inches wide.

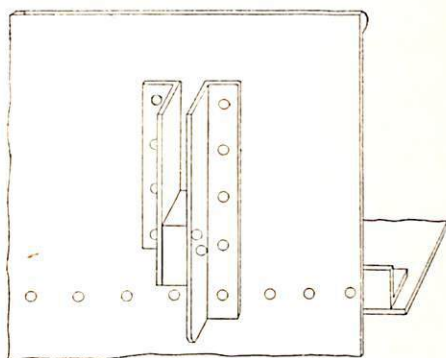
Hatch Rests.—The angles which support the ends of the hatches are called “hatch rests.” They must be at least $2\frac{1}{2}$ inches wide.



FORE AND AFTERS.

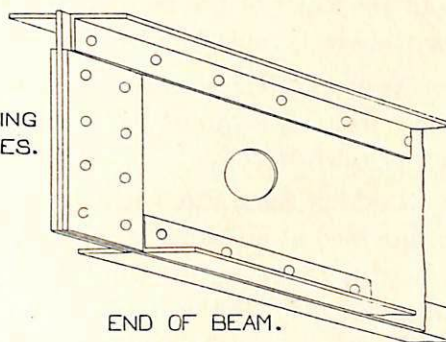


ATHWARTSHIP BEAMS.

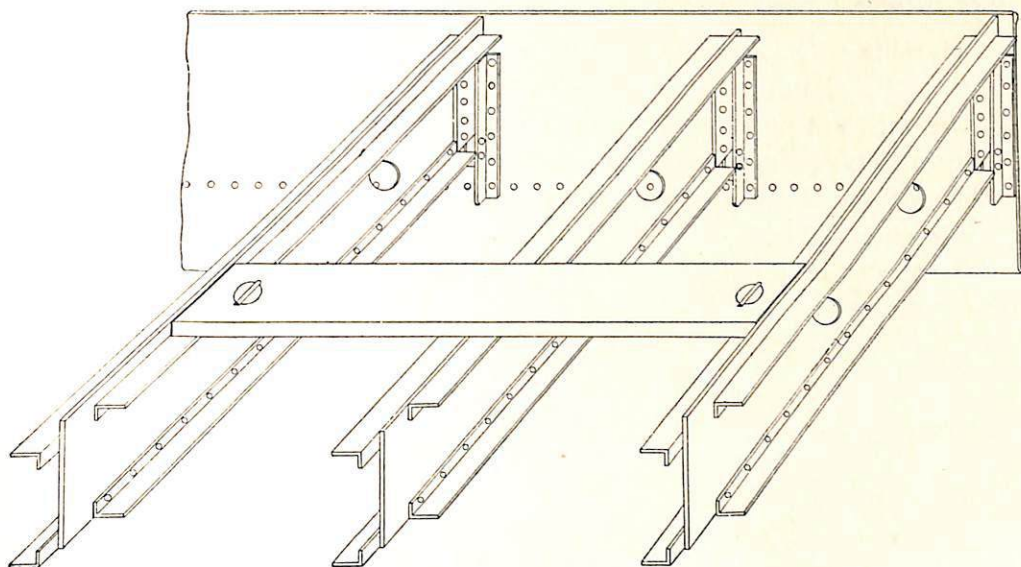


CARRIER.

DOUBLING
PLATES.



END OF BEAM.



HATCH BEAMS.

HATCH BEAMS AND COVERS—(Continued).

Cleats.—Cleats must be not less than $2\frac{1}{2}$ inches wide and must be set to fit the taper of the wedges. They must not be more than 2 feet apart and the end cleats must be within 6 inches of the hatch ends.

Wedges.—These must be of tough wood, at least 8 inches long and 2 inches wide. They must have a taper of 1 in 6 and must be $\frac{1}{2}$ inch thick at the toe, or narrow end.

Locking Bars, Etc.—Locking bars, or some equivalent arrangement, must be provided at all hatches in which the coamings are required to be 24 inches in height. (See "hatch coamings.") They must secure each section of hatches independently. If the hatch covers extend over more than one beam space, a locking bar must be provided at each end of each section of hatches.

At other hatchways in exposed positions on weather decks, ring bolts or other fittings for lashings, must be provided.

Marking.—The Factory and Workshops Acts require all hatches and beams to be plainly marked to indicate the hatch and deck to which they belong and their position therein. This, however, does not apply where all the beams and/or hatch covers in a ship are interchangeable : nor in respect of the marking of position when all the beams and/or covers of any one hatch are interchangeable.

The Acts also require that hand-grips of a suitable size are to be provided in all hatches.

Notes.

SUPERSTRUCTURES AND DECKHOUSES.

Lloyd's Dimensions.—*L.*

General.—A superstructure may be described as an erection above the upper deck, extending from side to side of the ship and forming a part of the main hull.

A deckhouse may be described as a comparatively light structure, more or less resembling a steel box, and used mainly for accommodation and similar purposes. It does not usually extend for the full width of the ship and is placed upon the ship's main hull, as distinct from forming an integral part of it.

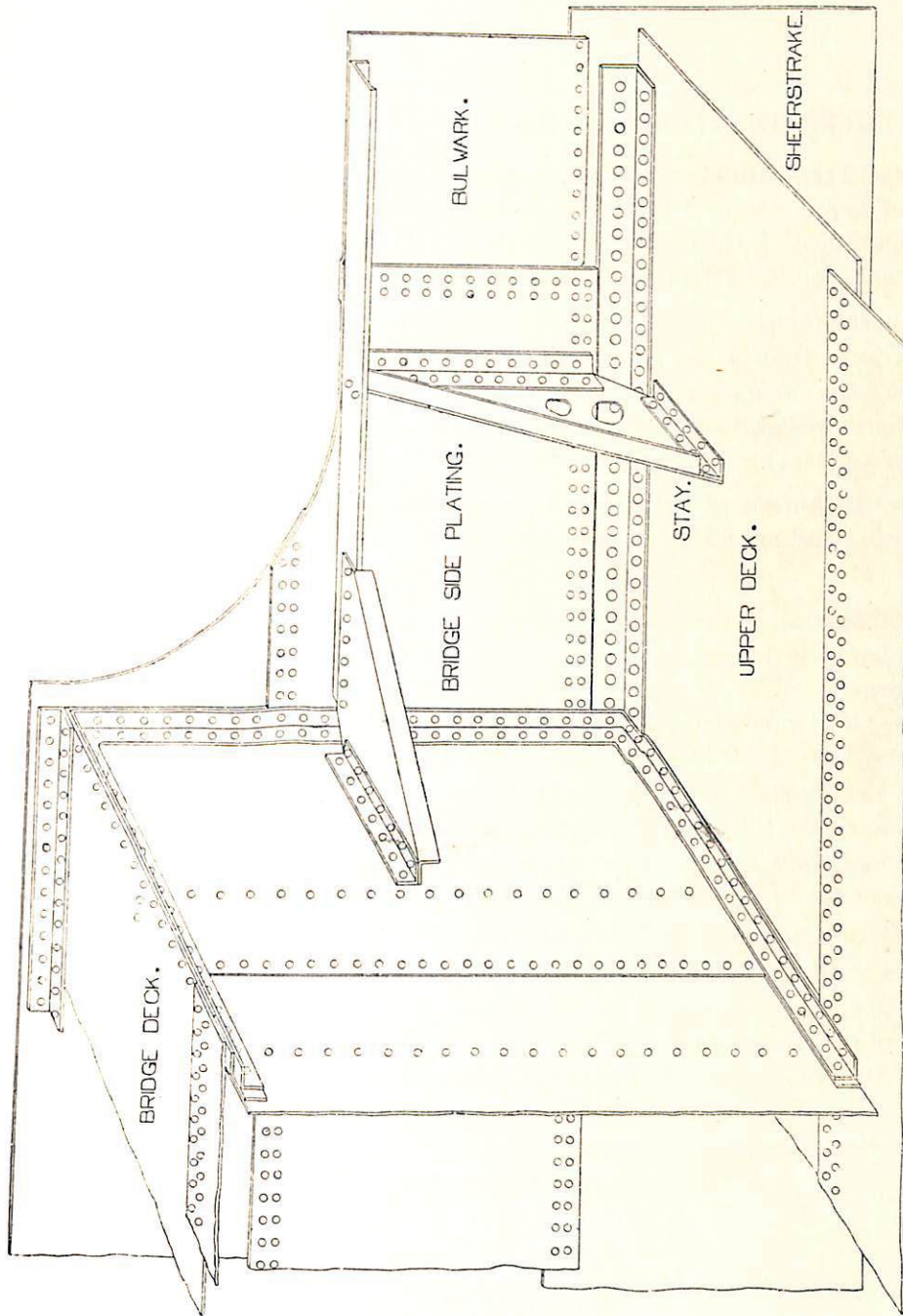
Forecastles and Poops.—These are usually comparatively lightly constructed. If they extend into the amidships half of the ship, however, the upper deck stringer and sheerstrake must be thickened, as for a long bridge.

Bridges.—Great care must be taken to preserve continuity of strength in the way of bridges, since the longitudinal bending stresses on the ship are greatest in their vicinity.

A "short bridge" is one which has a length of not more than 15 per cent. of the ship's length. It is constructed in the same way as a poop, except that the upper deck stringer and sheerstrake are thickened by 10 per cent. and 30 per cent., respectively, in the vicinity of its ends.

A "long bridge" is one which has a length of more than 15 per cent. of the ship's length. It must be more strongly built than a short bridge and may be required to be strengthened by partial bulkheads or web frames if it carries large deck houses. The upper deck stringer and sheerstrake are thickened by 25 per cent. and 50 per cent., respectively, in the vicinity of its ends.

Bridge Side Plating.—To avoid a sudden break of strength at the ends of a bridge, the bridge side plating must be tapered off into the bulwark plating. It is stiffened on its upper edge and is also supported by web plates, which must be placed within 5 feet of the ends of the bridge.



FITTING OUTSIDE BRIDGE.
BRIDGE FRONT BULKHEAD.

SUPERSTRUCTURES AND DECKHOUSES—(Continued).

Bridge Front Bulkheads.—These must be strong enough to resist the impact of heavy seas. The plating is fairly thick and is stiffened by bulb angles of from $5\frac{1}{2}$ inches to 11 inches deep. These stiffeners are spaced 30 inches apart and are attached by angle lugs at their heads and feet.

Poop Bulkheads.—If the poop covers a machinery space, or if it has a length of more than 40 per cent. of the ship's length, the poop front bulkhead must be of the same construction as a bridge front bulkhead. Otherwise, the plating may be slightly thinner, whilst the stiffeners may be angles of between 3 inches and 7 inches in depth.

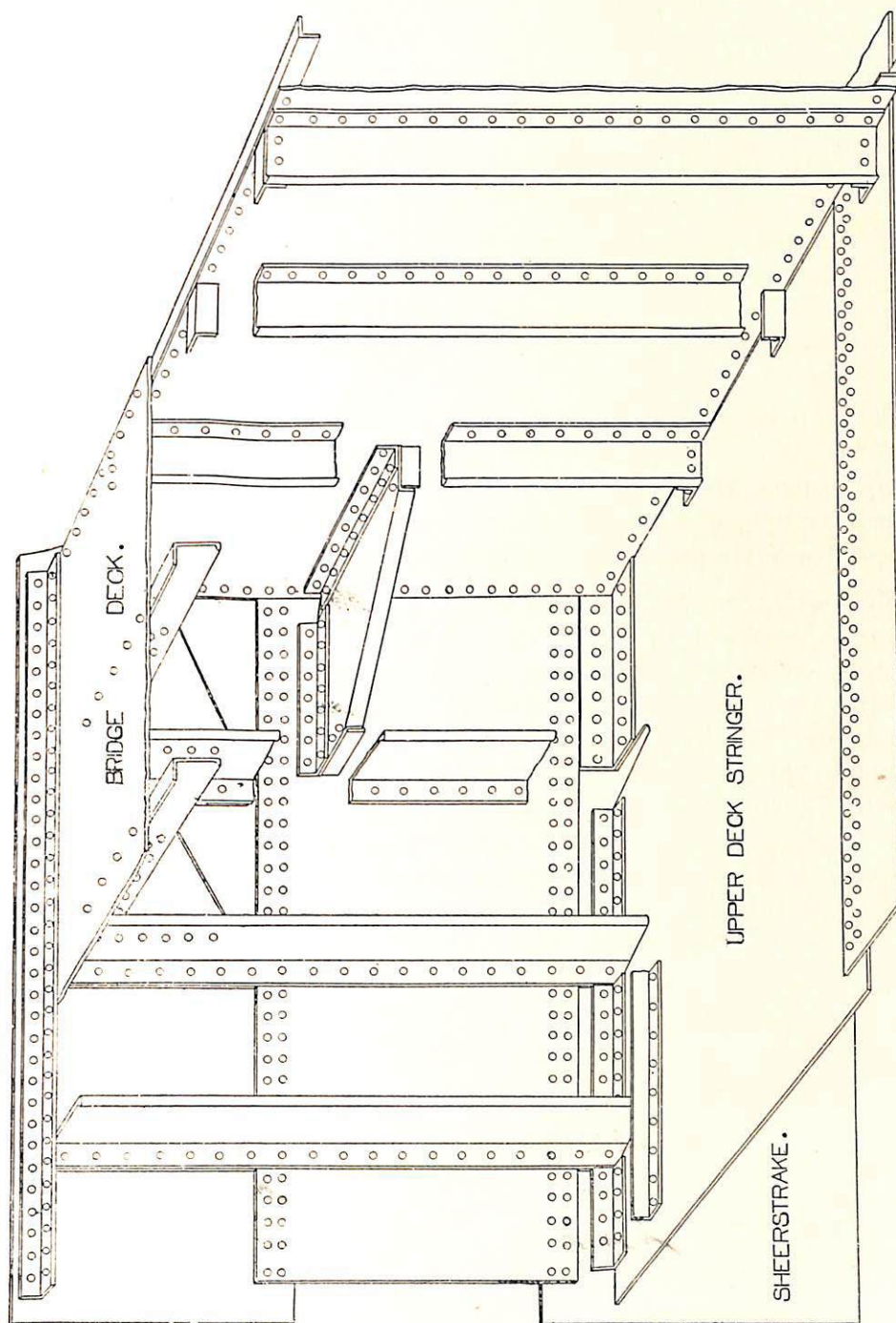
After Bulkheads of Bridges and Forecastles.—These have comparatively light plating and are stiffened by angles of between $2\frac{1}{2}$ inches and 4 inches in depth.

Deckhouses.—These are usually connected to the deck by single riveted angles, except in long deckhouses, where the angles may be double riveted at the corners.

The plating is strengthened by stiffeners, usually angles, spaced 30 inches apart on the front and sides of the house, and 36 inches apart on its after end. These stiffeners and their beams should, so far as possible, be fitted in line with the ship's main framing. They are attached at the head and foot by angle lugs, except where there are two tiers of deckhouses, when the stiffeners of the lower tier must have bracket attachments. Partial bulkheads or web frames may also be fitted, about 30 feet apart, to strengthen the sides and ends of the deckhouse.

All openings in the side plating of deckhouses must be properly framed and should have well-rounded corners. Large openings should have web frames fitted on either side of them, if possible. Continuous coaming plates should be fitted above and below doorways and similar openings.

The deck under the corners of a long deck house must be specially supported from below by means of intercostal girders and pillars, or by web frames.



FITTING INSIDE BRIDGE.
BRIDGE FRONT BULKHEAD.

HAWSEPIPES.

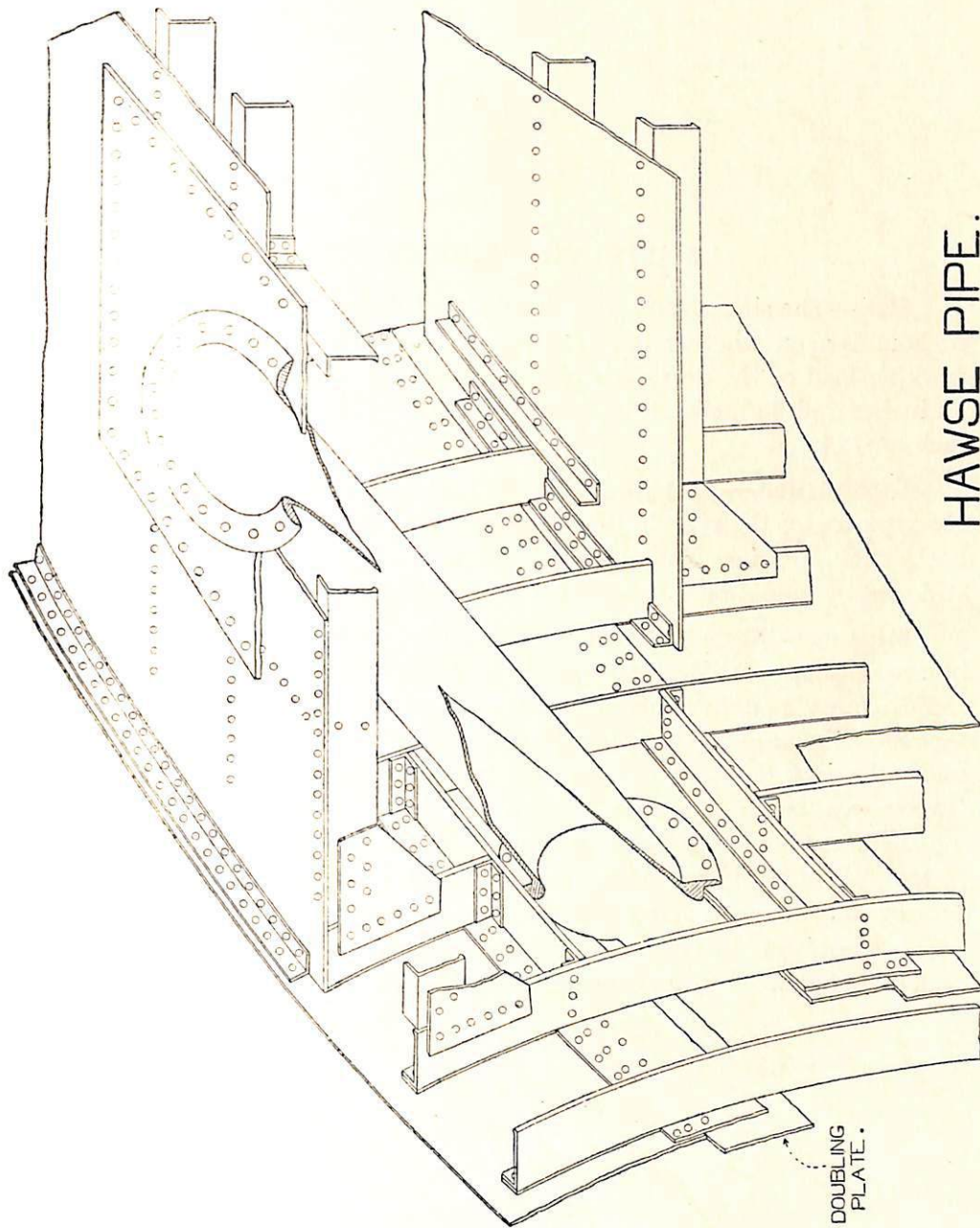
Construction.—Hawsepipes are usually made of cast-iron or cast-steel. They are very difficult to make from drawings, and so a wooden model is usually constructed in the ship and the hawsepipe cast from this.

Fitting.—There are several ways of fitting hawsepipes in a ship. In the pipe shewn in the sketch there are two lips, the upper one being riveted to the deck and the lower one to the shell plating.

Another common method of fitting hawsepipes is to have a lip at the lower end only. This lip is riveted to the shell plating. The upper end then merely pierces the deck and a heavy iron slab is bolted down over it.

The shell plating is doubled or thickened in the way of hawsepipes.

It is usually necessary to cut frames and beams, in order to allow the pipe to pass. In this case compensation is made by fitting short fore and aft pieces to support the cut ends, and the frames may be reinforced.



HAWSE PIPE.

MASTS AND DERRICK POSTS.

Size.—The size of a mast or derrick post depends on its length from deck to hounds; on whether it is stayed or not; and on the number and safe working load of the derricks which it carries. Its diameter may be between 12 inches and 30 inches, whilst the thickness of its plating may be from .24 inch to .72 inch.

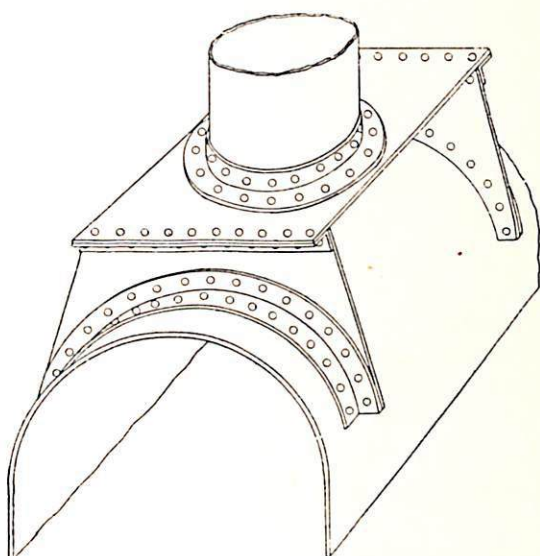
Construction.—Masts and derrick posts are usually built up of two or three plates on the round. The plating must be doubled or thickened at the heel, deck, derrick supports and hounds. Large masts are sometimes stiffened by angles or T-bars, fitted vertically inside them.

Stepping.—Masts exert a large downward thrust at their heels and must be strongly supported and stepped.

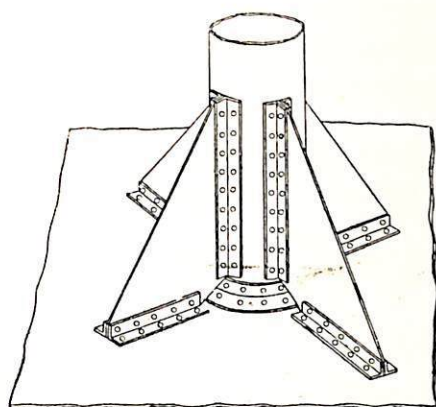
In most modern ships the masts are stepped in the 'tween decks. In this case, they are usually placed near a bulkhead, with large brackets fitted under the deck to transmit the thrust to the bulkhead. If this is not done, the 'tween deck must be specially pillared and stiffened below the heel of the mast.

Aftermasts are occasionally stepped on the tunnel. In this case, a special "stool" is fitted on top of the tunnel, which is given extra stiffening.

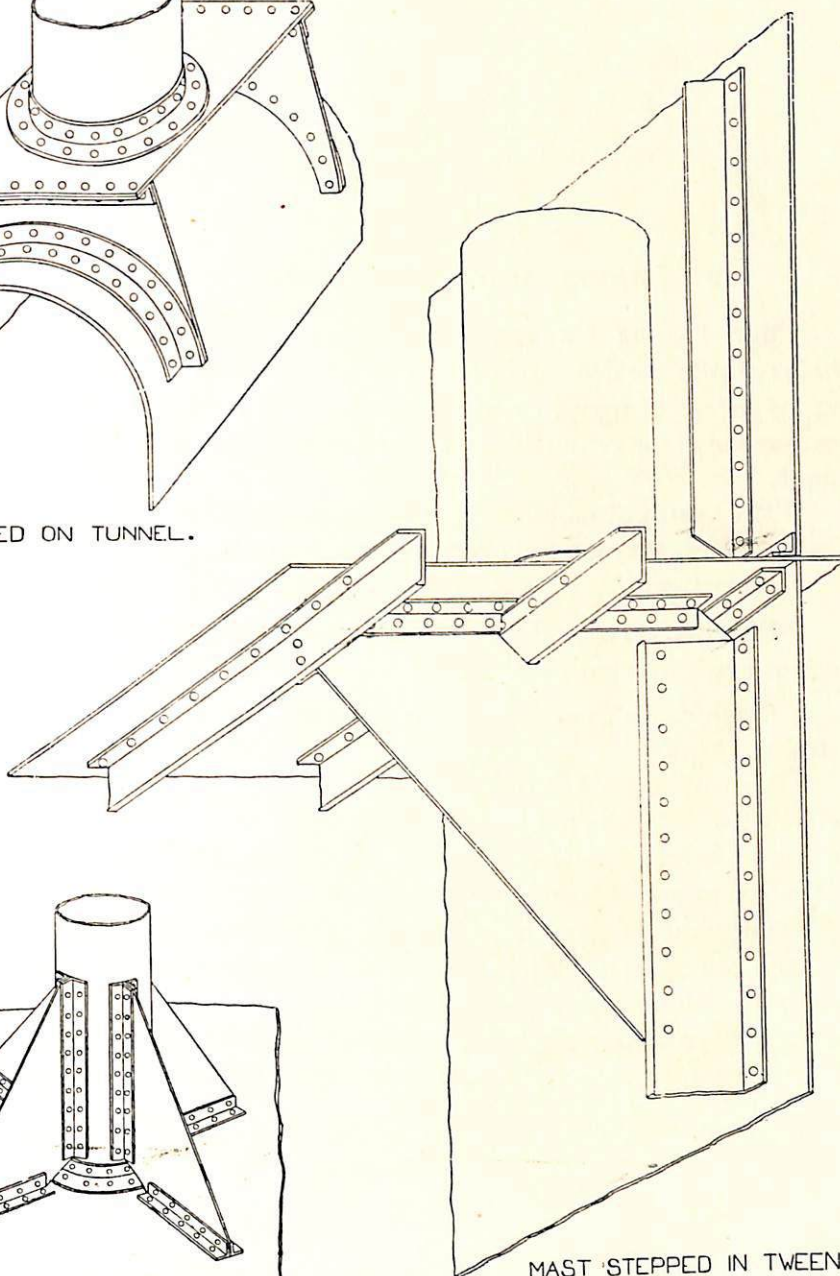
In single decked ships, the mast may be stepped on the centre keelson or inner bottom. In modern ships, however, it is often stepped on the upper deck and supported by an arrangement of brackets, known as a "tabernacle."



MAST STEPPED ON TUNNEL.



TABERNACLE.



MAST STEPPED IN TWEEN
DECK NEAR BULKHEAD.

MASTS.

MASTS AND DERRICK POSTS—(Continued).

Mast Passing Through Deck.—Where a mast passes through a deck, a hole is cut in the deck and framed by an angle bar. The mast may be wedged-up by means of wooden wedges and the joint made watertight by means of a canvas cover, or the angle bar may be a tight fit and be riveted directly to the mast.

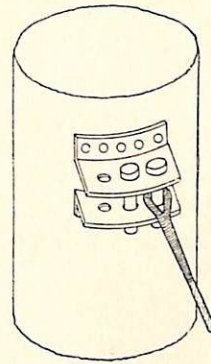
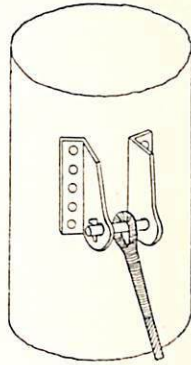
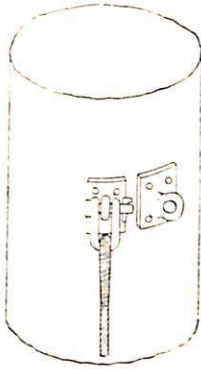
The beams often have to be cut to allow the mast to pass through them. In this case, the cut ends are supported by short fore and aft beams called "mast partners."

Riveting.—The end laps of mast plating are to be treble riveted and the seams single riveted.

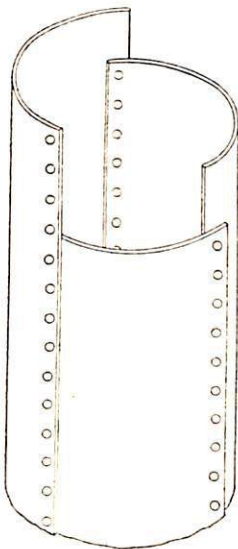
Rigging.—All masts and derrick posts of over 35 feet in length must be stayed.

Two shrouds must be fitted on each side of stayed masts. Their feet are connected to "chain plates," attached to the deck or sheerstrake, which must be strengthened in the way of them. At their heads, they may be attached in one of several ways, examples of which are shewn in the sketches.

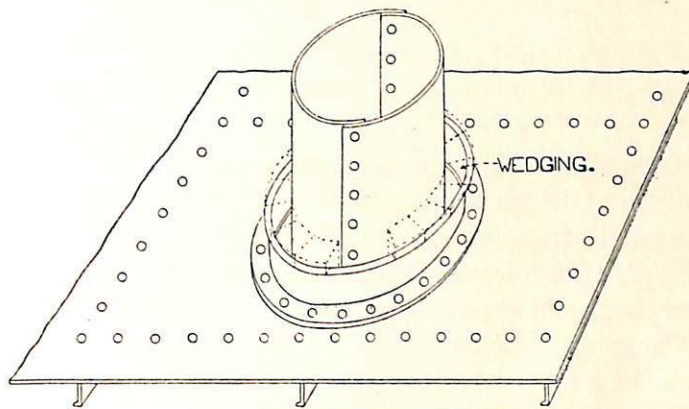
The shrouds must be of $2\frac{1}{2}$ inch wire on masts which carry no derricks; 4 inch wire on masts carrying 4-ton derricks; and 5 inch wire on masts carrying 8-ton derricks. They must be spread so that their feet reach the deck at a distance, forward of and abaft the mast, equal to one-quarter of the ship's beam, or one-quarter of the length of the mast, whichever is greater.



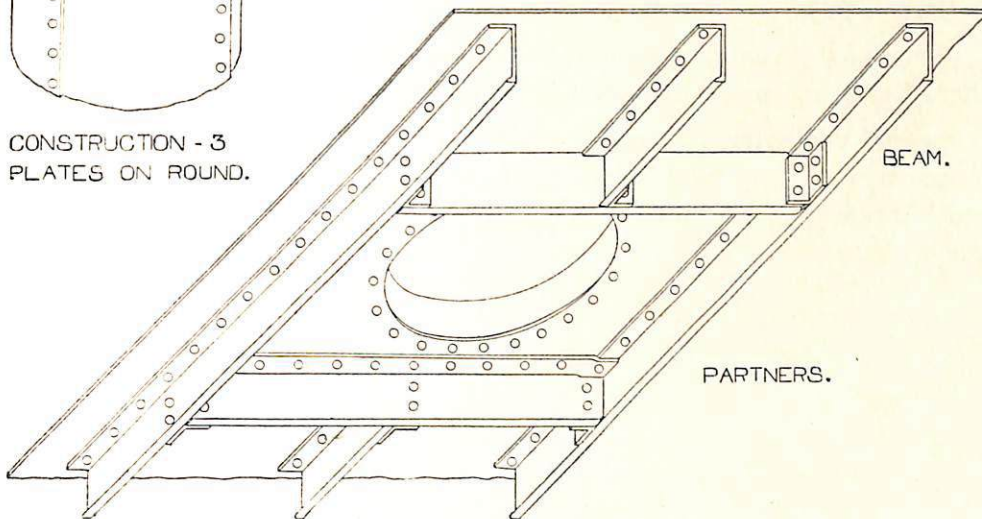
CONNECTION OF RIGGING AT HEAD.



CONSTRUCTION - 3
PLATES ON ROUND.



MAST PASSING THROUGH DECK.



MASTS

VENTILATORS.

General.—It is very important that ventilators should have sufficient strength. Otherwise, if one were to carry away in bad weather, a large amount of water might find its way below deck.

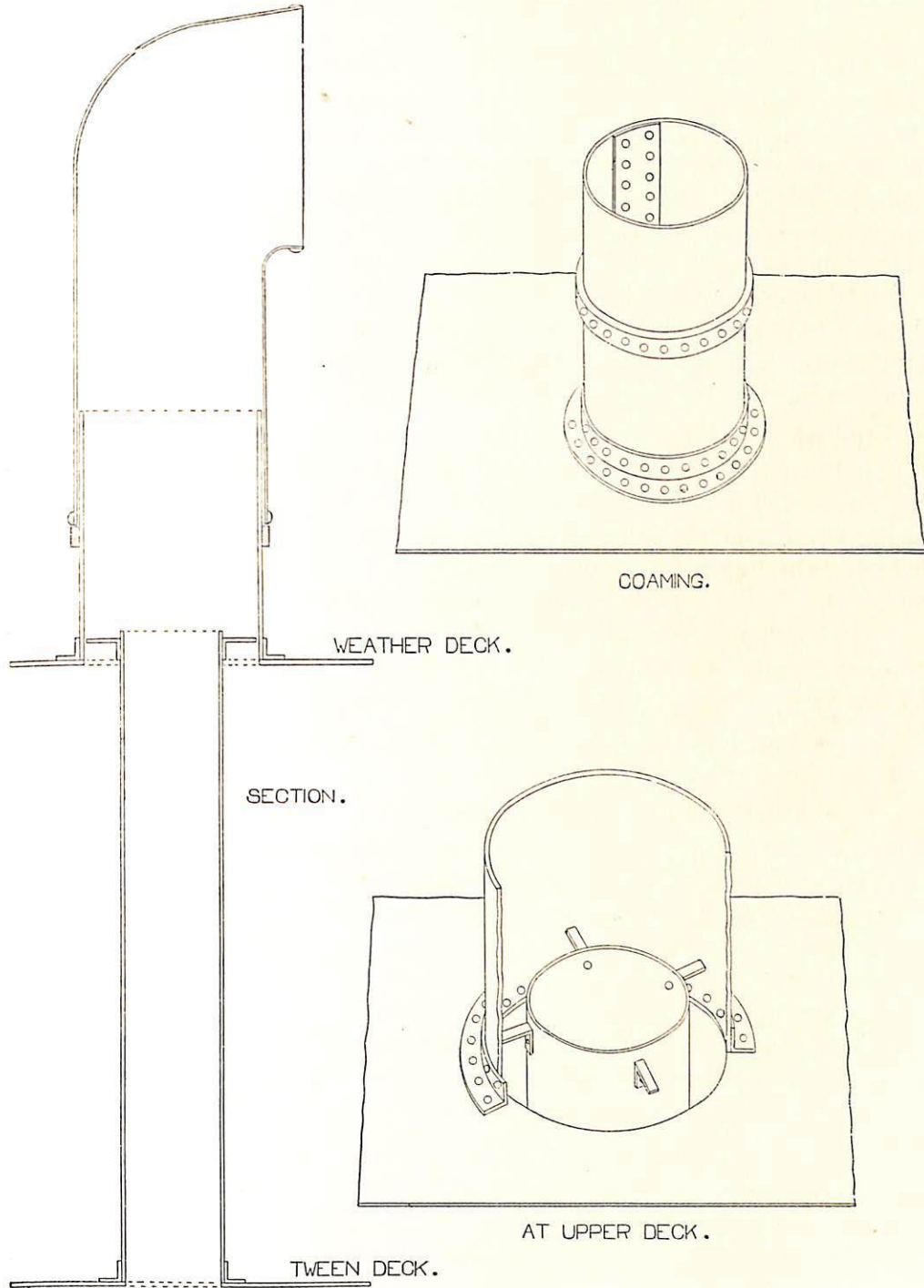
Coamings.—The height of coamings must be not less than 36 inches on upper decks which are exposed to the weather and for one-quarter of the ship's length from forward on all superstructure decks. Aft one-quarter of the ship's length from the stem on superstructure decks and on raised quarter decks, the height may be 30 inches.

Coamings which are over 36 inches high must be specially supported. This is done by brackets, similar to a tabernacle, or by some similar arrangement.

Decks.—The deck plating is to be stiffened in the way of ventilators.

Covers.—All ventilators must have proper plugs and canvas covers or some other efficient means of sealing the coamings when the cowls are unshipped.

Special Ventilators.—Ventilators leading to the tunnel and to tanks must be made watertight and must be capable of resisting water pressure. Ventilators leading to tanks for oil fuel should have gauze fitted over their mouths.



VENTILATORS.

INSULATED HOLDS.

General.—To prevent heat from entering insulated holds, all ironwork of the ship's hull, except the 'tween decks, is insulated. It is necessary to seal all scuppers and drains so that warm air or taint cannot enter through them and also to insulate sounding pipes and thermometer tubes from the decks. Special arrangements must be made to prevent oil from leaking into the holds from adjacent tanks.

The holds are usually cooled by drawing air over nests of brine pipes in a "cooler" at one end of the hold. This air is delivered to all parts of the hold by means of air ducts, whilst the spent air is drawn back into the cooler by other ducts.

Insulation.—Various materials may be used for insulation, but granulated cork is the most common. This is kept in place by some form of lining inside the frames and under the beams. Sometimes, this lining consists of tongued and grooved matchboarding, nailed to battens (or "grounds") which are bolted to the frames: in many modern ships it consists of plywood or sheet metal, attached to the frames and beams by special clips.

The hatchways are sealed by wooden "plug hatches," fitted under the ordinary hatches and beams. Access to bilges and double bottoms is provided by further plug hatches, fitted over bilges and manholes.

Cargo Battens.—These must be fitted on the decks and sides, to allow free circulation of air and to protect the insulation.

Protection from Oil.—If the cellular double bottom under the hold is intended to carry oil, the bottom insulation must be laid on athwartships battens, so that there is a 2 inch air space between insulation and tank top. Pillars, doubling plates and gussets must be welded to the inner bottom. Tank side brackets and floors must be attached to the margin plate by T-bars or by welding; whilst manhole cover fastenings are not to pass through the inner bottom plating.

Deep tanks intended to carry oil must be separated from insulated holds by cofferdams, unless the bulkhead is completely welded and there is a 2 inch air space between it and the insulation.

Piping.—All pipes, including air and sounding pipes, must be insulated. Thermometer tubes must be insulated from the deck plating and must have an inside diameter of at least 2 inches.

All drains which lead to the bilges must have liquid-sealed traps in them.

PIPES TO TANKS AND BILGES.

General.—It is obviously necessary to have pipes to tanks and bilges in order that tanks may be filled or emptied, and bilges periodically pumped out. The sketch shows diagrammatically how the suction pipes are arranged throughout the ship.

Valve Chest.—At their engine room end the pipes run into a "Valve Chest," which is a large box connected by a pipe to pumps. Each pipe from the tanks or bilges has its own valve in the chest, so that any one or all of the pipes can be connected to the pumps as desired.

There are usually at least two valve chests in a ship, one for the fore end and one for the after end. Sometimes two or three chests are used for each end of the ship, each controlling a different section.

Bilge Suctions.—Bilge suction pipes run fore and aft along the bilges. They may run through the lightening holes in the tank side brackets, but more often they are led up and run along the tops of the bilges. They must not pass through deep tanks, double bottom tanks, or oil fuel bunkers, unless this is unavoidable.

To prevent the accidental flooding of holds the bilge suction pipes must be fitted with non-return valves (i.e. valves which will allow water to flow through them in one direction only.) All valves in the valve chest which control the bilge suction must be of this type, so that whilst the bilges can be pumped out it is impossible to fill them accidentally.

The suction are usually placed at the after end of each hold, since ships normally trim by the stern and consequently the water collects at the after ends of the bilges.

When the cellular double bottom extends out to the ship's side there are no proper bilges. In this case the holds drain into sunken compartments in the double bottom, which are known as "wells." These wells may be formed by fitting watertight floors right across the ship, so as to enclose one or two frame spaces in the bottom. More frequently they are boxes built up of steel plates and placed in either wing of the ship. Each well must have a capacity of at least six cubic feet.

Tank Suctions.—The suction pipes to tanks in the fore end of the ship are usually led through the double-bottom. They pass through the lightening holes in the floors, to which they are attached by special clips. In the after end they are usually led through the tunnel.

The suction ends of the pipes must be placed so that any water in the tank can be pumped out when the ship is on an even keel and has a list of five degrees either way. To this end it is usual to fit suction at the centre line and in either wing of large tanks. In small tanks near the ends of the ship, one suction is fitted at the centre line only. Tanks which are sub-divided at the centre line must, of course, have at least two suction, one on either side.

PIPES TO TANKS AND BILGES—(Continued).

Peak Tank Suctions.—If peak tanks are used for ballast they must have suction lines leading to them. The fore peak suction must have a screw-down valve fitted on it, forward of the collision bulkhead, and capable of being worked from above the load waterline.

Deep Tank Suctions.—These must be arranged so that they can be fitted with "Blank Flanges," i.e., plates which can be bolted on to the ends of the pipes to prevent water from passing in or out. When the tanks are being used for solid cargo, the ballast pipes should be blanked-off and the bilge suction left open. When the tanks are used for water ballast or oil fuel, the bilge suction should be blanked-off and the ballast pipes left open.

Pipes at Bulkheads.—For the method of passing pipes through watertight bulkheads see the section on "Bulkheads."

Strum Boxes.—A box with perforated sides, called a "Strum Box," is fitted over the end of each suction pipe. This box strains the water when it is being pumped out and thus prevents solid matter from being drawn into and choking the pipes or valves.

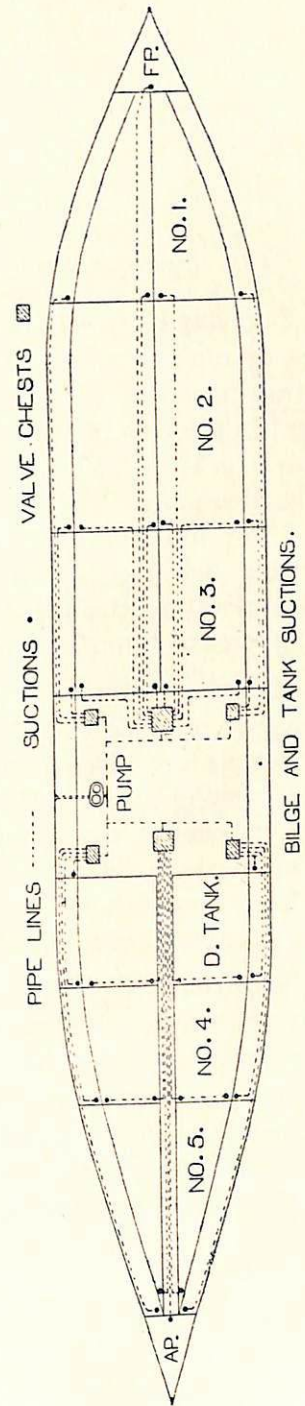
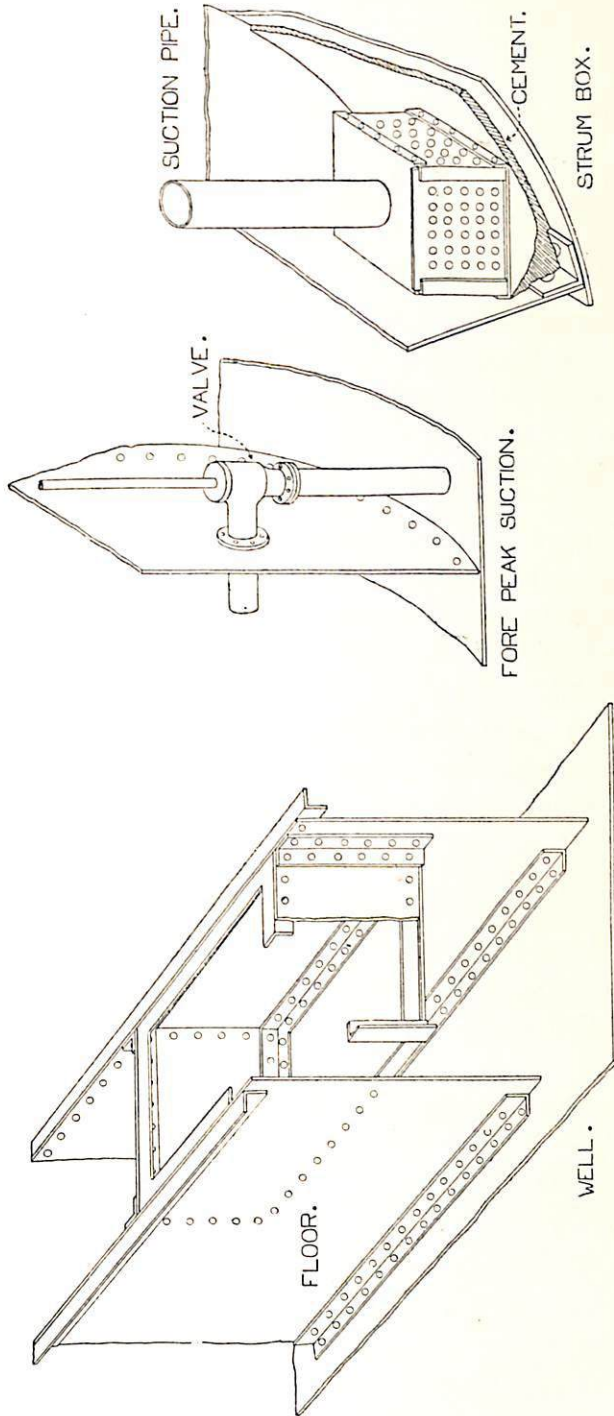
The perforations are not to be more than $\frac{3}{8}$ inch in diameter and are to have a total area of at least twice that of the pipe. It must be possible to clear the box without disconnecting the pipe and this is usually done by making one side of the box removable.

Air Pipes.—These must be fitted to tanks in order that air may escape when the tanks is being filled. They must be fitted at the outboard corners of the tank, at the opposite end from the filling pipes, or at the highest point of the tank top. The total area of these pipes must normally be equal to that of the filling pipes.

Air pipes must extend above the load water line. If they extend above the freeboard deck they are to be 36 inches above that deck, 30 inches above raised quarter decks, or 18 inches above other superstructure decks immediately above the freeboard deck.

Filling of Tanks.—There are no separate pipes for filling tanks—they are always filled through the suction pipes.

Deep tanks and peak tanks are always filled by pumping the water into them. Double bottom tanks are sometimes filled in this way, but if there is plenty of time in which to fill them they are often "run up," i.e., their pipe lines are connected to an inlet valve in the engine room and the water is allowed to flow in by gravity.



PIPING.

PIPES TO TANKS AND BILGES—(Continued).

Sounding Pipes.—In order that the depth of water in tanks and bilges may be ascertained sounding pipes must be fitted to them. These usually consist of straight vertical pipes, and they must extend to above the load waterline, except in the case of those to tanks below engine spaces. They must not be of less than $1\frac{1}{4}$ inches inside diameter, and must be placed as near as possible to the suction pipes.

There must be some arrangement at the bottom end to prevent the sounding rod from wearing through the bottom of the tank. Doubling plates are often fitted for this purpose, but sometimes the end of the pipe has a plug screwed into it and holes are cut to allow the water to run in.

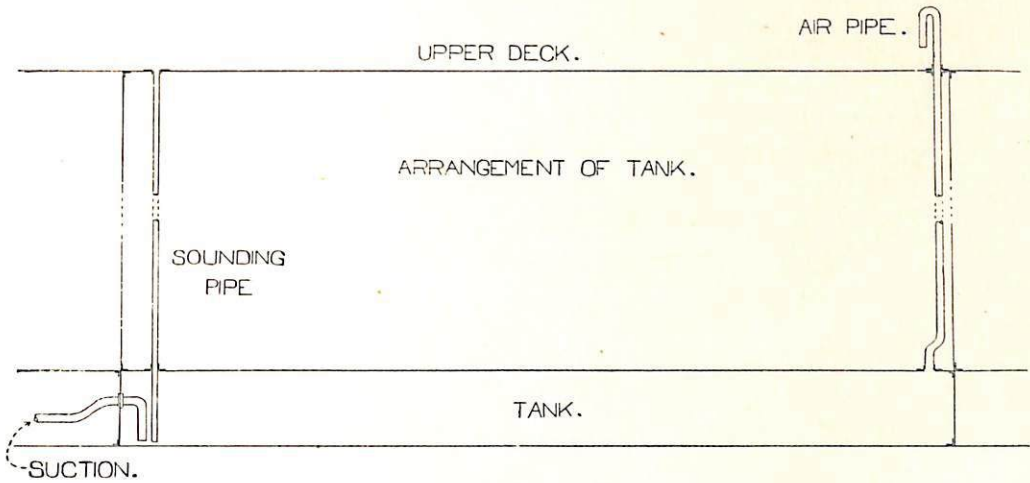
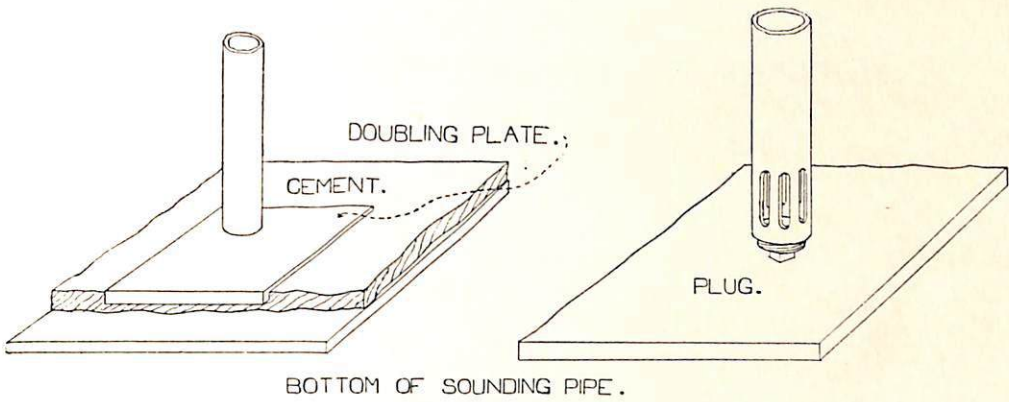
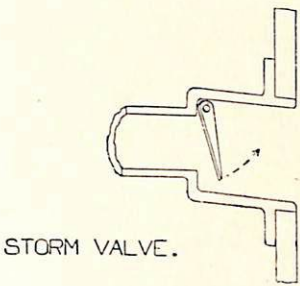
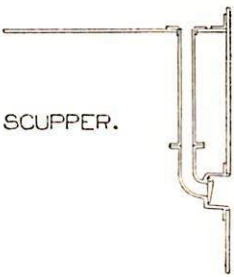
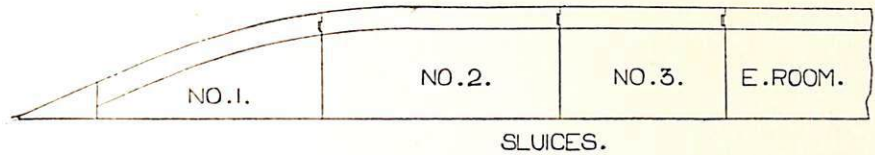
Sluices.—Sluices were originally valves fitted in bulkheads in the way of the bilges, or at the centre line in the case of ships with open floors. They took the place of bilge suction, and, when it was desired to drain the bilges, the sluices were opened and the water allowed to run back into the engine room bilges, whence it was pumped out. They had a number of disadvantages and are now obsolete.

The name "sluice" is now sometimes applied to the sliding watertight doors fitted in the bulkheads of passenger ships.

Scuppers.—Scuppers must be fitted at all decks. Those from decks below the superstructure deck must lead down to the bilges, or must be fitted with screw down, non-return valves.

Scuppers from inside superstructures may lead to the bilges: or they may lead overside if they have either screw down non-return valves, or storm valves, according to the type of superstructure.

Most other scuppers must lead overboard.



PIPING.

SECTION II.
THE CONSTRUCTION OF OIL TANKERS.

OIL TANKERS.

General Requirements.—Oil tankers carry a large amount of more or less inflammable oil in bulk. Consequently they must be built somewhat differently from other ships.

Consider the requirements for a modern tanker :—

- (a) Tankers are particularly subject to longitudinal stresses and are also assigned less freeboard than ordinary ships. Consequently, they need to be more strongly built.
- (b) If the tanks are not quite full, the oil will wash around and set up very large stresses. This is overcome by fitting longitudinal bulkheads (which also give considerable longitudinal strength) and a large number of transverse bulkheads, which divide the ship into reasonably small tanks.
- (c) All work must be oiltight, even under stress, to prevent leakage of the cargo.
- (d) The risk of fire must be considered and a special system of ventilation adopted, to allow the escape of gasses. The engines are always fitted aft in a modern tanker, thus doing away with the shaft tunnel, which was always a source of danger in early tankers, owing to oil leaking into it. Cofferdams are also fitted in certain parts, to “ seal ” the tanks from the rest of the ship.
- (e) Continuity of strength must be maintained. This is, of course, important in all ships, but it presents a greater problem in tankers than in other vessels. It must be remembered that tankers are divided into a number of comparatively small separate compartments and that all longitudinal girders, etc., are cut at transverse bulkheads.
- (f) Since the cargoes carried are liquid ones, it is necessary to have pipe-lines and pumps to handle them. In order to reduce the risk of fire, the pumps should not be in the engine room, but in separate compartments known as “ pump rooms.”

OIL TANKERS—(Continued).

General Arrangements.—Many of the early tankers were built on a system of web framing. This is now obsolete, having been replaced by the longitudinal framing system.

The longitudinal sections and plans shewn in the plate illustrate the general arrangements of two tankers. Sketch A shows a ship having one longitudinal bulkhead at the centre line and an expansion tank.

Sketch B shows a tanker of the latest type, having two longitudinal bulkheads and no expansion trunk: this is the standard type quoted in Lloyd's Rules.

Abbreviations Used in Sketches "A" and "B."

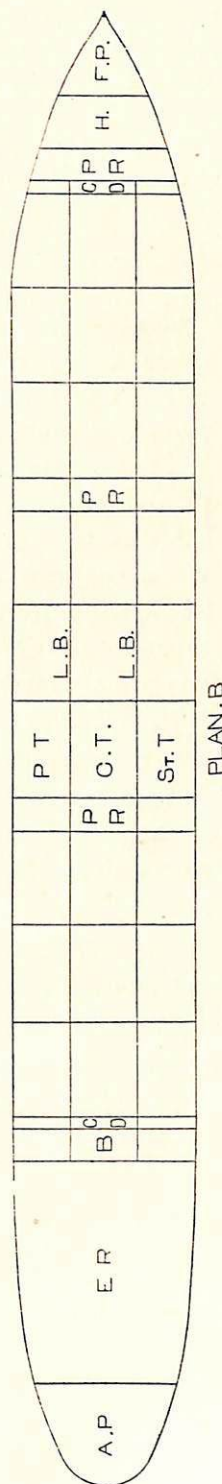
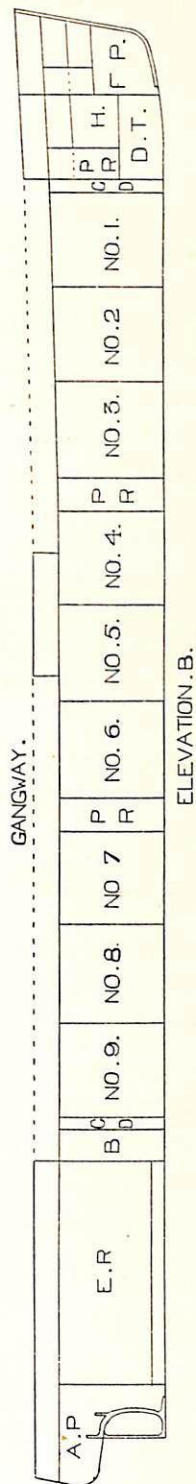
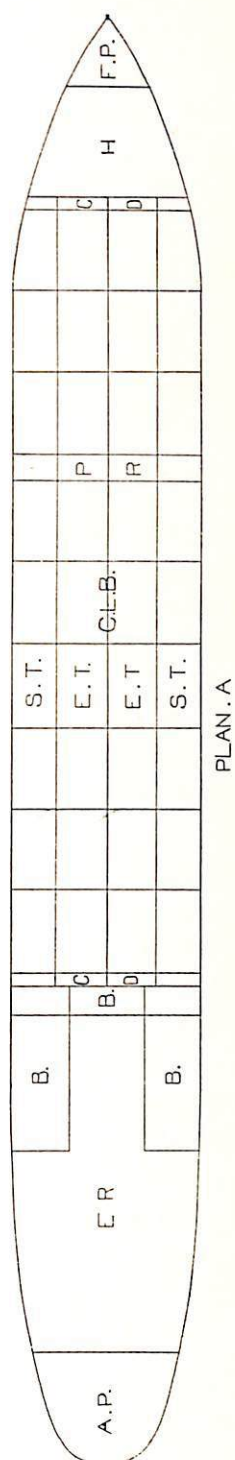
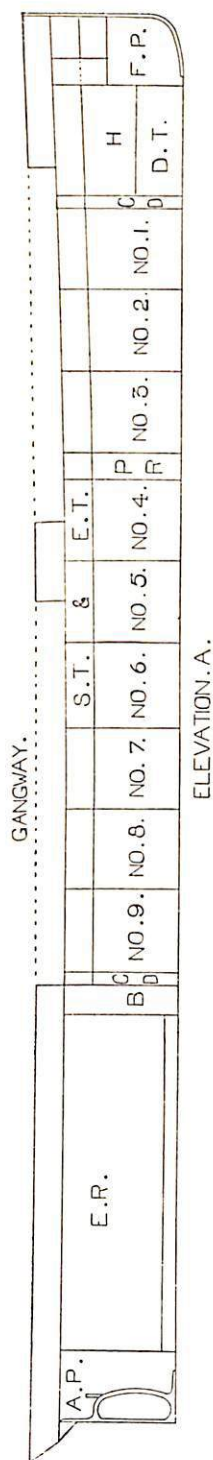
A.P.	..	After Peak	E.T.	..	Expansion Trunk
B.	..	Bunker	F.P.	..	Fore Peak
C.D.	..	Cofferdam	H.	..	Hold
C.L.B.	..	Centre Line Bulkhead	L.B.	..	Longitudinal Bulkhead
C.T.	..	Centre Tank	P.R.	..	Pump Room
D.T.	..	Deep Tank	P.T.	..	Port Tanks
E.R.	..	Engine Room	S.T.	..	Summer Tanks
		St. T.	..		Starboard Tanks

Cofferdams.—These are double transverse bulkheads, at least ^{2'6"}~~3~~ feet apart, the space between which can be filled with water when the ship is loaded. They must be fitted at each end of the main system of cargo tanks and must extend right across the ship from the keel to the upper deck, so as to seal the oil tanks from the rest of the ship.

Pump Rooms.—Pump rooms are necessary in order that the oil may be pumped into or out of the ship, without having to pass through the engine room. This minimises the danger of fire. In older ships, only one pump room was fitted, but in the latest tankers, two or three such rooms are fitted.

Deep Tanks.—The deep tanks are usually fitted at the fore end of the ship, in order to counterbalance the weight of the engines, which tends to make the ship trim by the stern when she is light.

Bunkers.—A "Cross Bunker Tank" is usually fitted just forward of the engine room. Further bunker oil may be carried in the deep tank and in the double bottom which is fitted under the engine room.



OLDER TYPE.

General.—The half midship section facing this page shews a tanker which has a centre line bulkhead, expansion trunk and summer tanks, arranged as shewn by sketch "A" in the plate on "General Arrangements." This type was built almost exclusively for many years, but is now giving place to the single decked, two bulkhead type which is today quoted as Lloyd's standard.

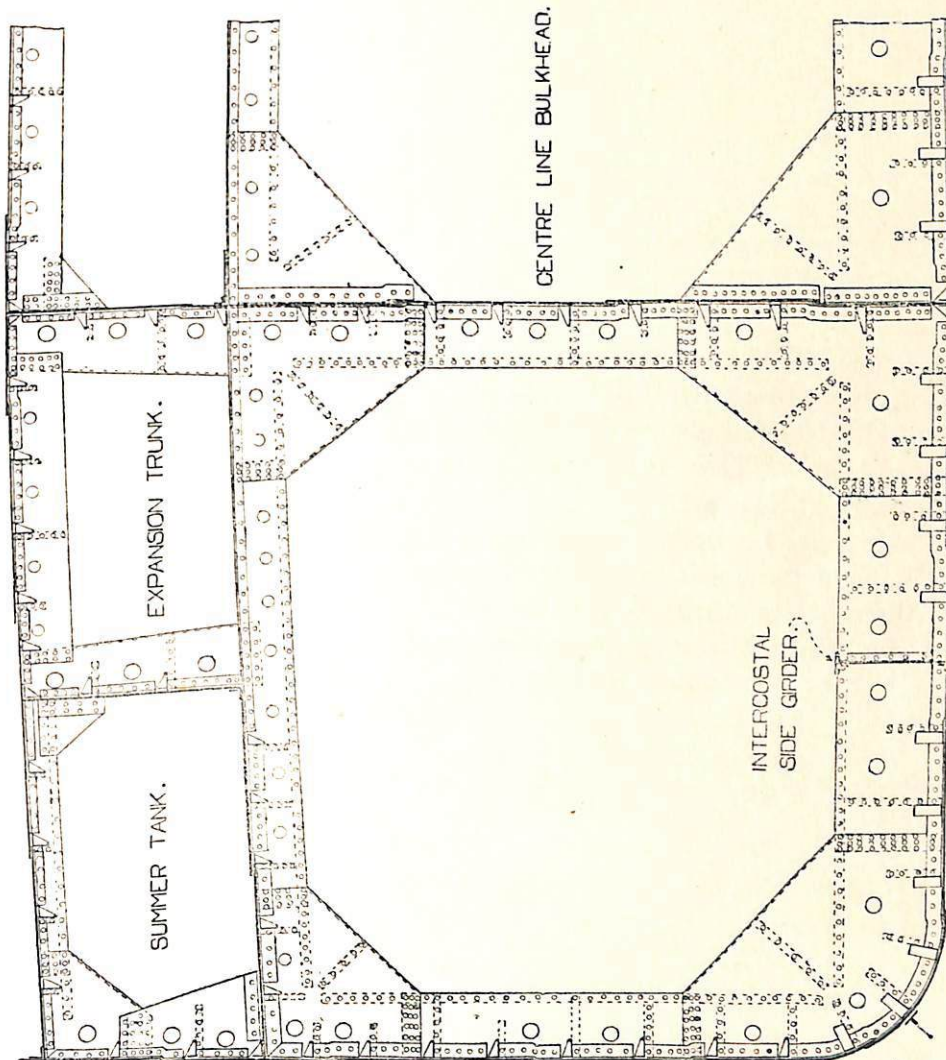
The ship is built on the Isherwood System of framing. She has deep, widely spaced transverse frames, known as "Transverses," through which pass longitudinal frames, called "Longitudinals." Note how the corners of the transverses are connected together by means of flanged brackets.

No cellular double bottom is fitted in the main part of the hull, but one is usually fitted under the engine and boiler rooms.

The Expansion Trunk.—Oil expands and contracts with changes of temperature and so the tanks cannot always be kept exactly full. The expansion trunk is built to reduce the free surface of the oil, which might otherwise reduce the ship's stability and also set up considerable structural stresses.

Summer Tanks.—When light oils are being carried, the main tanks alone may not be large enough to bring the ship down to her marks. This difficulty can be overcome by filling the summer tanks.

Centre Line Bulkhead.—The centre line bulkhead sub-divides the tanks longitudinally and thus helps to reduce the effect of free surface. It also gives much longitudinal strength and acts in lieu of pillars.

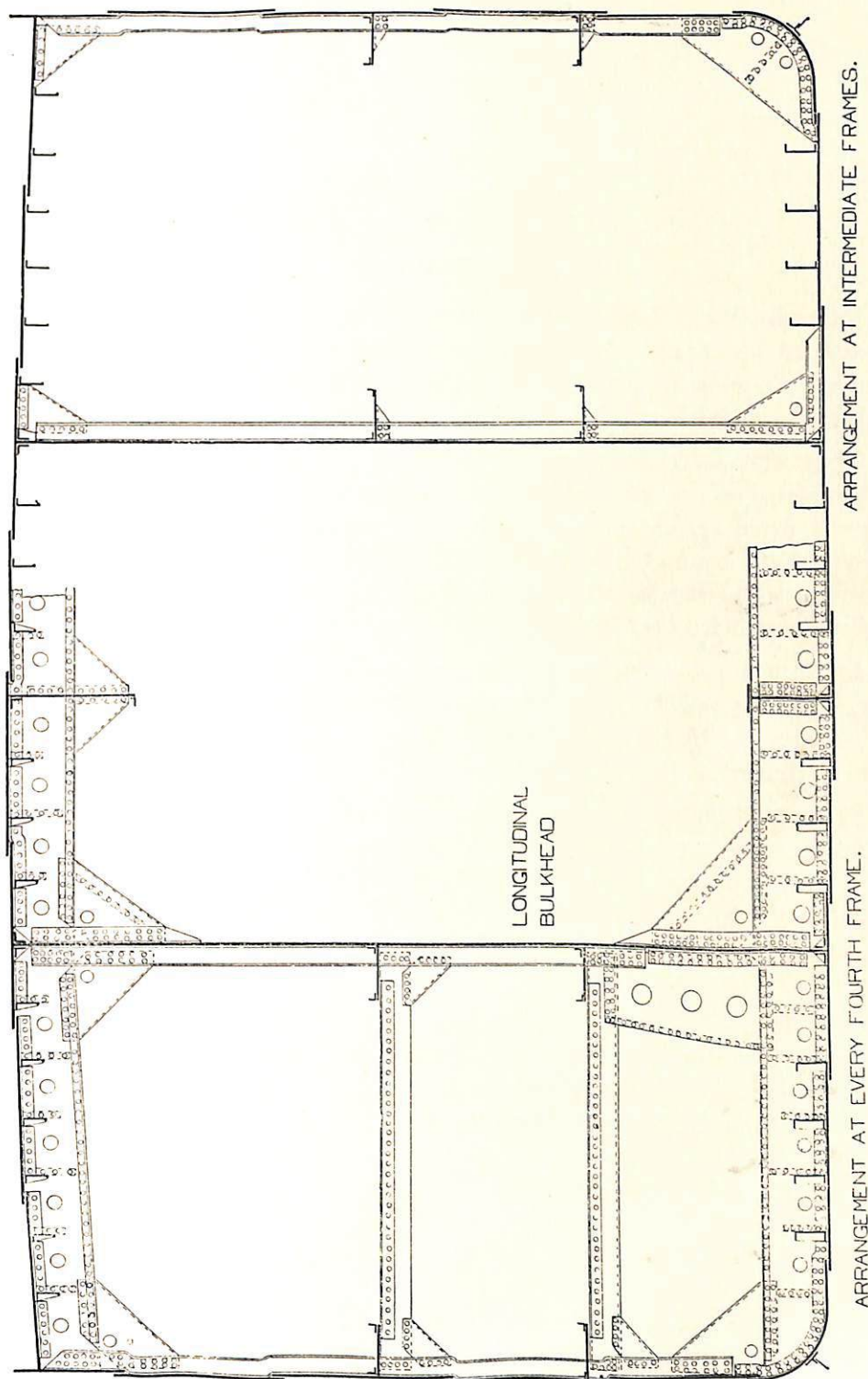


OLDER TYPE

LATEST TYPE.

The sketch shews the latest type of tanker, quoted in Lloyd's Rules ; arranged as shewn by sketch " B " in the plate on " General Arrangements." Two longitudinal bulkheads are fitted and divide the ship into port, centre and starboard tanks. There is no expansion trunk or summer tanks, as they are unnecessary in this case.

The ship may be built on the Isherwood System, with longitudinal framing throughout, similar to that shewn in the sketch of the older type of tanker. Alternatively, it may be built on the Isherwood Combination System, as shewn here. In this, the longitudinals are retained in the bottom and under the decks, but the side framing is of the ordinary type.



LATEST TYPE.

FRAMING.

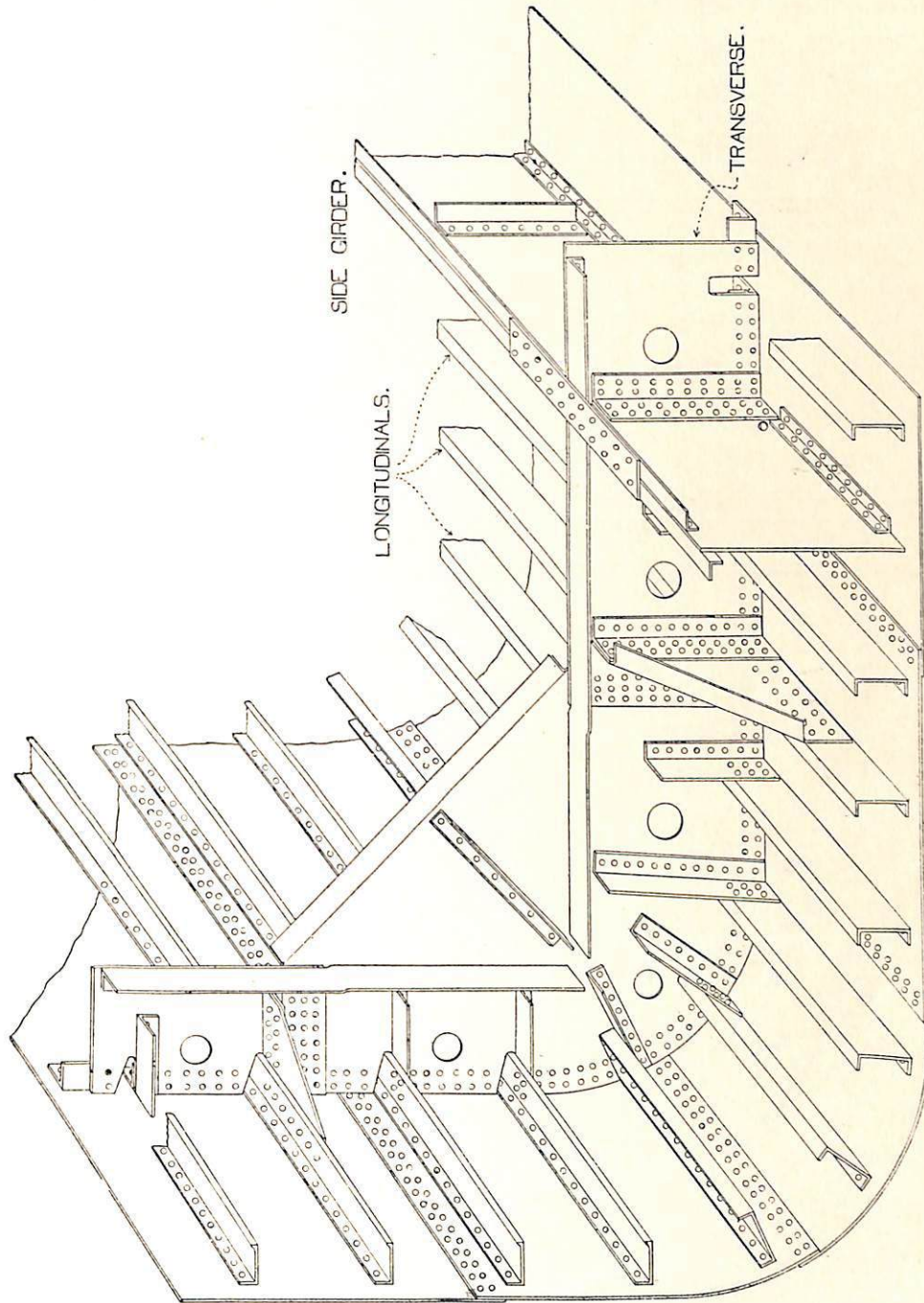
General.—When longitudinal framing is fitted on the ship's sides and longitudinal bulkheads, the transverses extend right around the tank. If transverse framing is used for the sides and longitudinal bulkheads, the transverses are retained in the bottom and under the decks only.

Transverses.—Transverses must not be spaced more than 12 feet apart. Their inner edges are stiffened by angles or flanges and they must have angle stiffeners fitted across them at each longitudinal. The bottom and deck transverses are connected to the side transverses, or to the ship's sides and longitudinal bulkheads, by flanged brackets. Fore and aft "tripping brackets" are fitted near the toes of the transverse ones.

Longitudinals.—These are usually bulb-angles or channels and are spaced 30 inches apart. They pass through notches in the transverses, to which they are attached by the angle stiffeners. They are cut at transverse bulkheads and are attached to them by brackets.

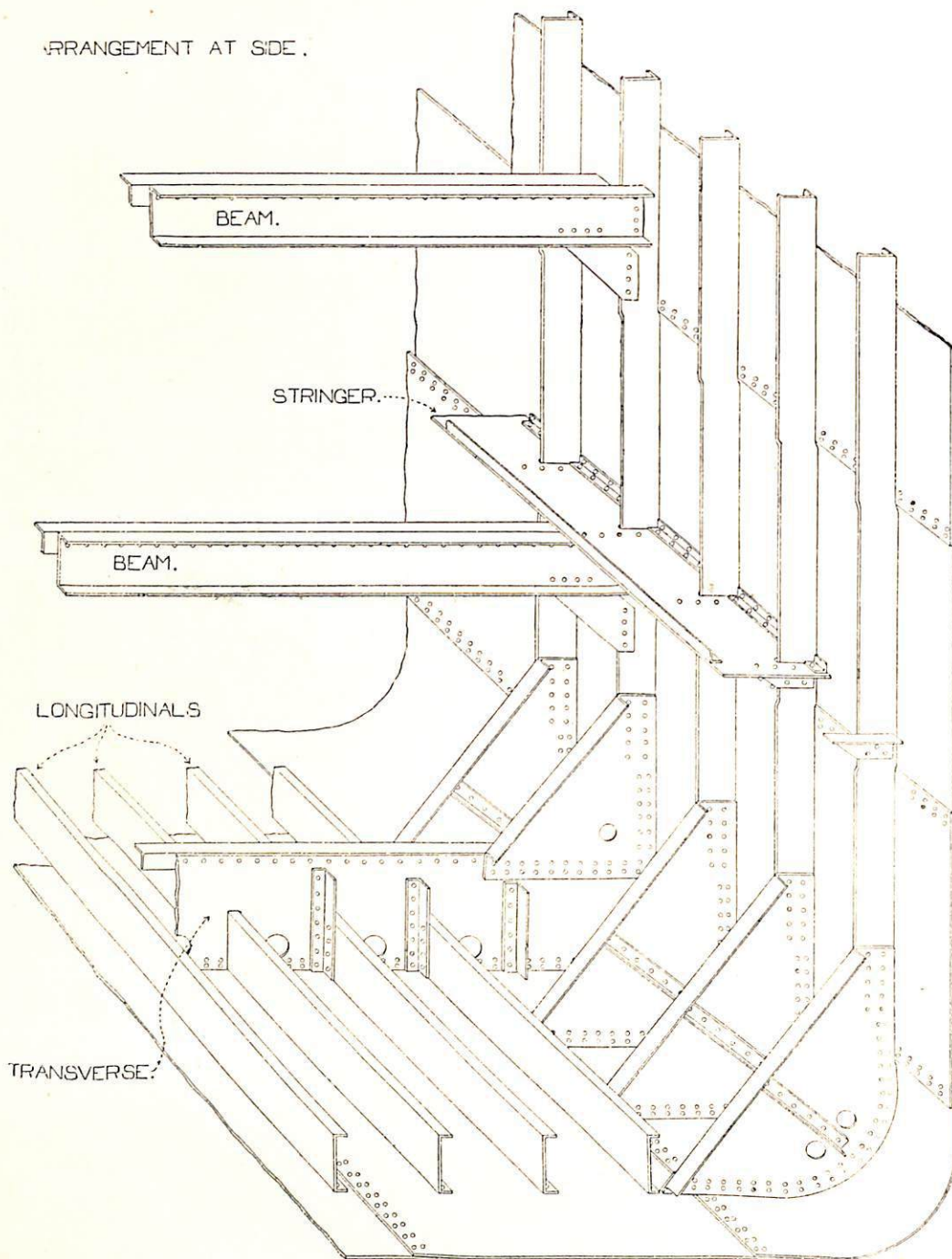
Ordinary Framing.—If this is fitted on the ship's sides and longitudinal bulkheads, each frame is connected at its head and foot to flanged brackets, which must extend at least to the nearest longitudinal. At the bilge, these brackets must cover the entire round of the bilge. Side stringers must be fitted at the ship's sides and equivalent horizontal girders on the longitudinal bulkheads.

Cross Ties.—In the two-bulkhead type ship horizontal cross-tie beams must be fitted in the wing tanks between the ship's sides and the bulkheads. These may be either built or rolled sections and are connected to the vertical webs or horizontal girders by brackets.

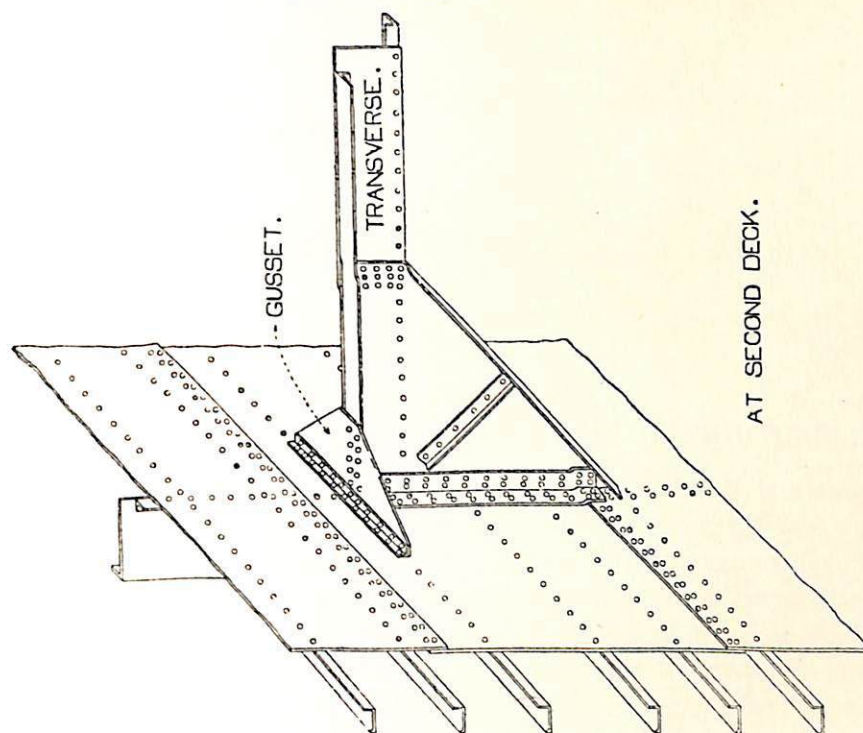


BOTTOM AND SIDE TRANSVERSES.

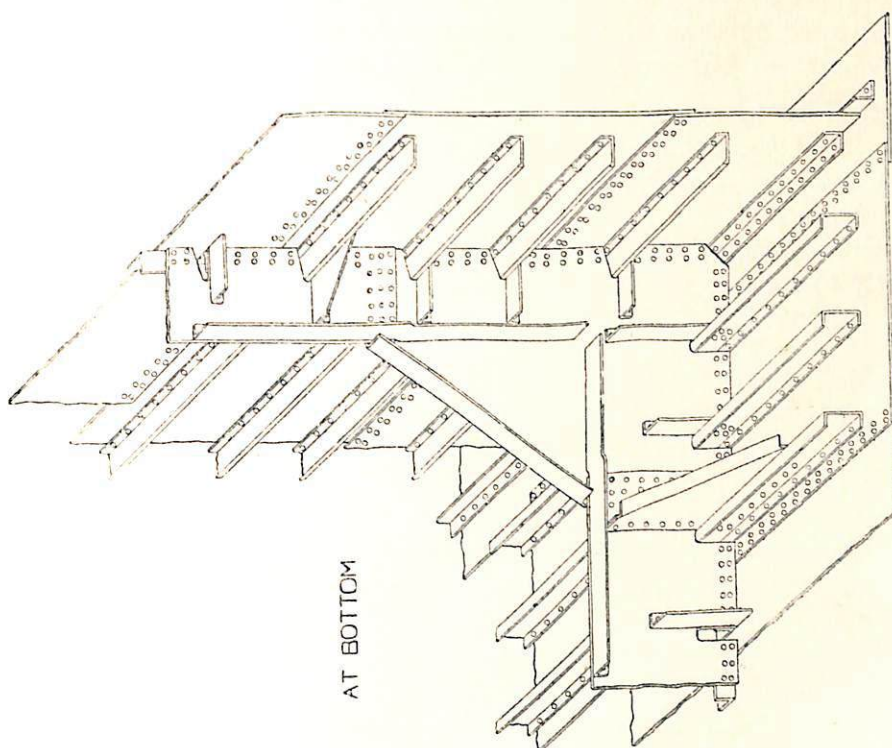
ARRANGEMENT AT SIDE.



LATEST TYPE.



AT SECOND DECK.



AT BOTTOM

LONGITUDINAL BULKHEAD.

LONGITUDINAL BULKHEADS AND CENTRE GIRDERS

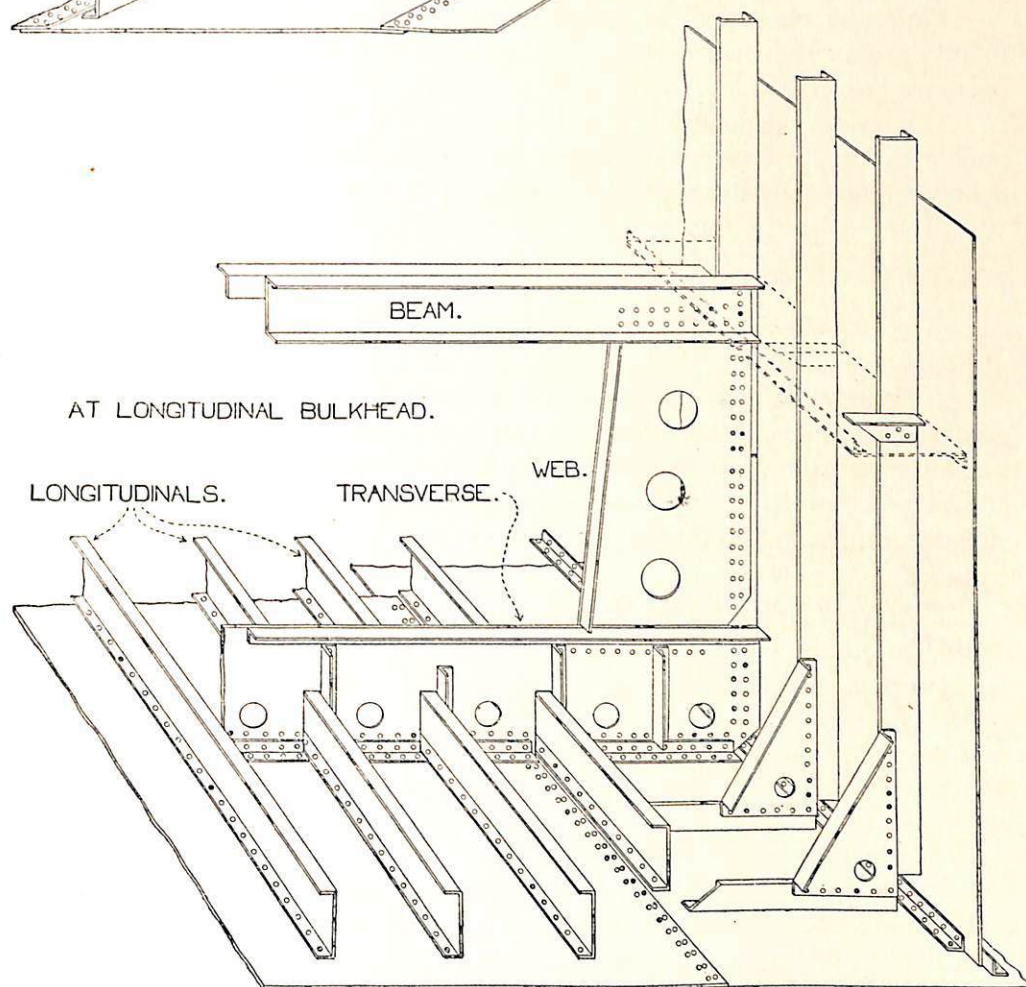
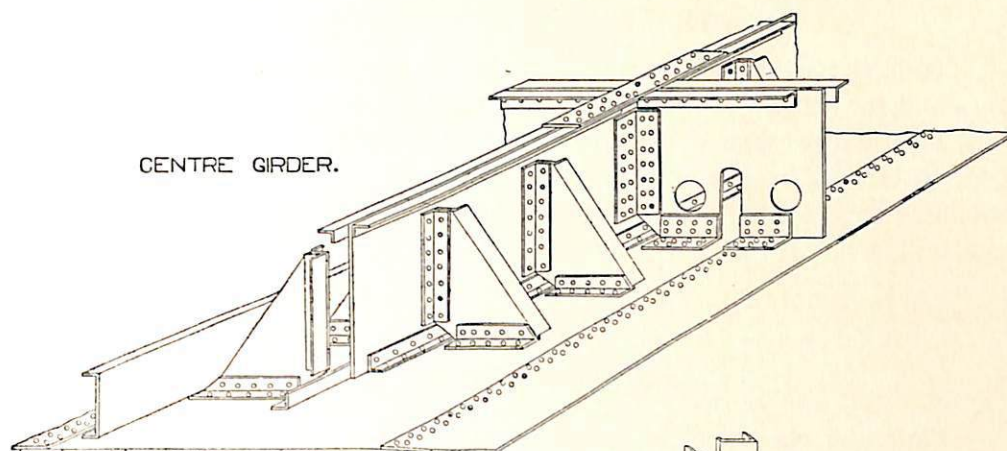
Longitudinal Bulkheads.—These must be oiltight throughout the cargo tanks but may be perforated in pump rooms and cofferdams. Beyond the ends of the oil compartments, they must be scarphed into the ship's structure.

The stiffeners may be horizontal or vertical, bracketed at their ends and supported by webs or horizontal girders. The sketches in this book shew longitudinal stiffeners for the older type ship and vertical ones for the latest type. The general system of construction is similar in either type, however, except that the second deck is omitted in the latest type.

Corrugated bulkheads are sometimes used. These do not have ordinary stiffeners on them, but are supported by webs or horizontal girders.

Centre Line Girders.—In the two bulkhead-type of ship, a centre girder must be fitted to support the keel plate. This is supported by vertical brackets, not more than 6 feet apart, flanged or stiffened by angles on their inner edges.

A centre line girder is also fitted under the deck, partly to give strength and partly to act as a washplate. This girder is usually very similar to that fitted at the keel.



LATEST TYPE.

TRANSVERSE BULKHEADS.

Transverse bulkheads are constructed in the same way as longitudinal ones and the general rules for their construction are similar.

The sketches shew the construction of a transverse bulkhead in the older type of tanker. In the later type of tanker, its construction would be very similar, except that the second deck, summer tanks and shelf-plate would be omitted.

SHELL PLATING.

Particular care must be taken to ensure that continuity of strength is maintained in the shell plating, and great care is necessary with regard to openings cut in it.

The riveting depends on the thickness of the plating. End laps may be double to quadruple riveted, with a pitch of between $3\frac{1}{2}$ and $4\frac{1}{2}$ diameters. Seams are normally double riveted, with a pitch of $3\frac{1}{2}$ to 4 diameters.

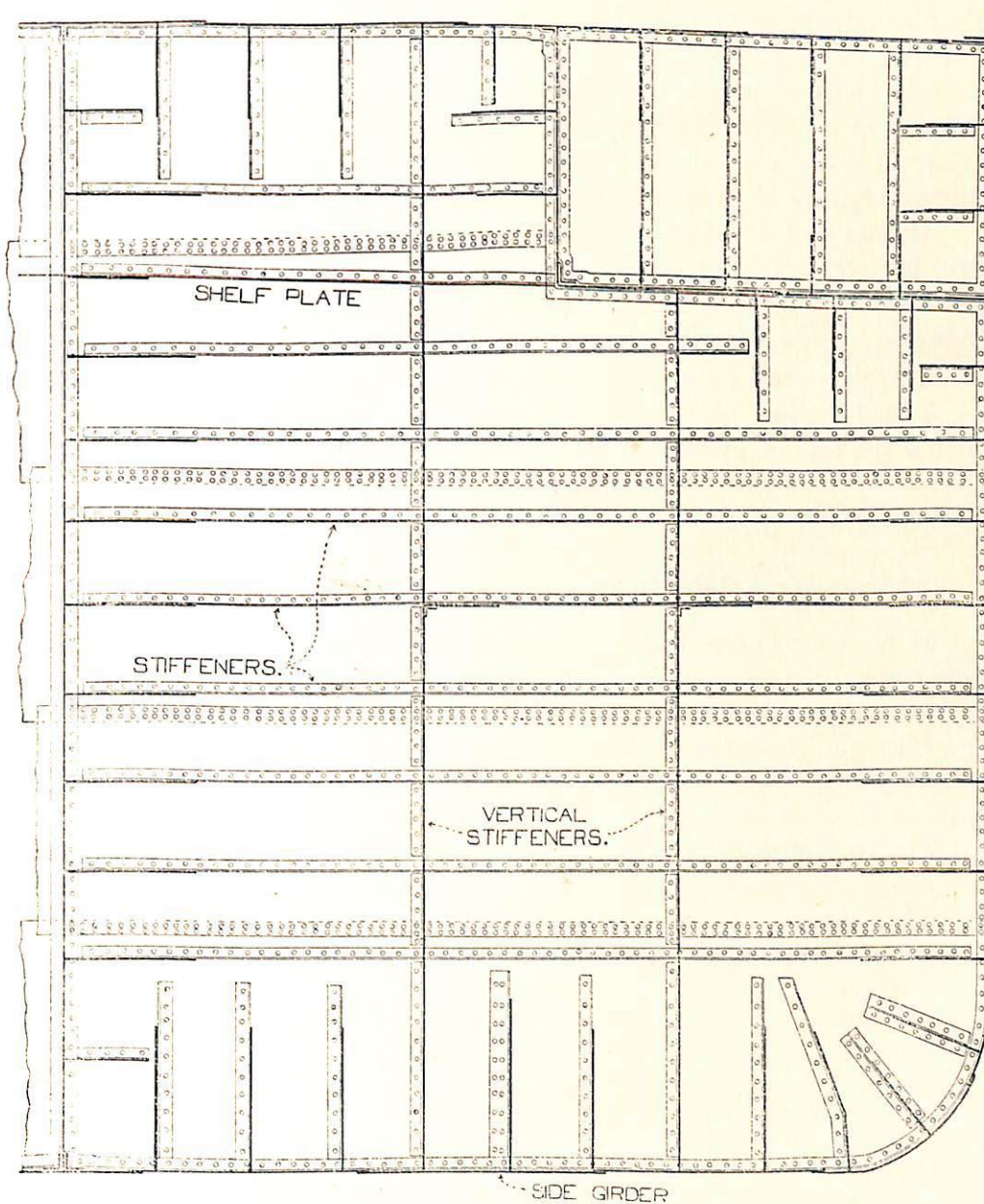
DECKS.

Continuity of strength is most important in decks, on account of the great longitudinal stresses which are experienced in tankers. The deck plating has to be maintained at its midship thickness for one-half of the ship's length amidships. Special strengthening precautions must be taken at the ends of superstructures and all deck openings must be smooth and have well-rounded corners.

The riveting depends on the thickness of the plating. End laps may be double to quintuple riveted, whilst seams must be double riveted. The pitch is between $3\frac{1}{2}$ and 4 diameters.

HATCHWAYS.

To avoid weakening the deck, the hatchways should be as small as possible and should have well-rounded corners. The hatch covers must, in most cases, be of steel and they may be required to have stiffeners on them. Those covering oil compartments must have fastenings spaced 18 inches apart for circular hatchways, or 15 inches apart for rectangular hatchways. The end fastenings must be within 9 inches of the hatch ends.



TRANSVERSE BULKHEAD.

MERCHANT SHIP CONSTRUCTION

SUPERSTRUCTURES, DECKHOUSES, ETC.

The ship must have a forecastle, covering at least 7 per cent. of her length. She must also have a poop or deckhouse, long enough to enclose the machinery casings.

The ends of poops, bridges and deckhouses must be constructed and stiffened in much the same way as for ordinary ships, unless the poop front bulkhead forms part of the machinery casings, in which case it must have stiffeners spaced 24 inches apart and bracketed at the head and foot.

Houses protecting pump room openings must be strongly built and must have hinged steel doors, with 24 inch sills.

Open rails must be fitted for at least half the length of the weather deck. Bulwarks may be used for the other half unless there are trunks standing above the deck, when rails must be fitted throughout.

The ship must have permanent gangways, at superstructure deck level, joining the bridge, machinery space and crew's accommodation.

FRAMING AT THE FORE END.

If, as is usual, the ship has ordinary transverse framing forward of the cargo tanks, she must have the following strengthening arrangements :—

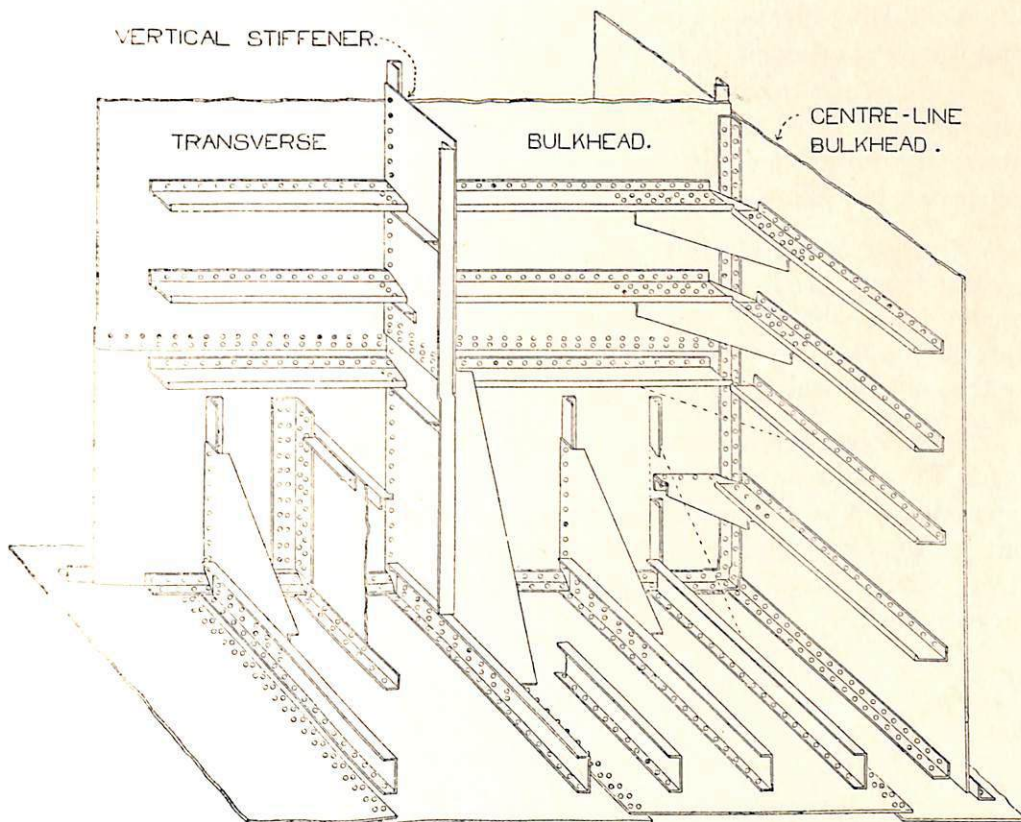
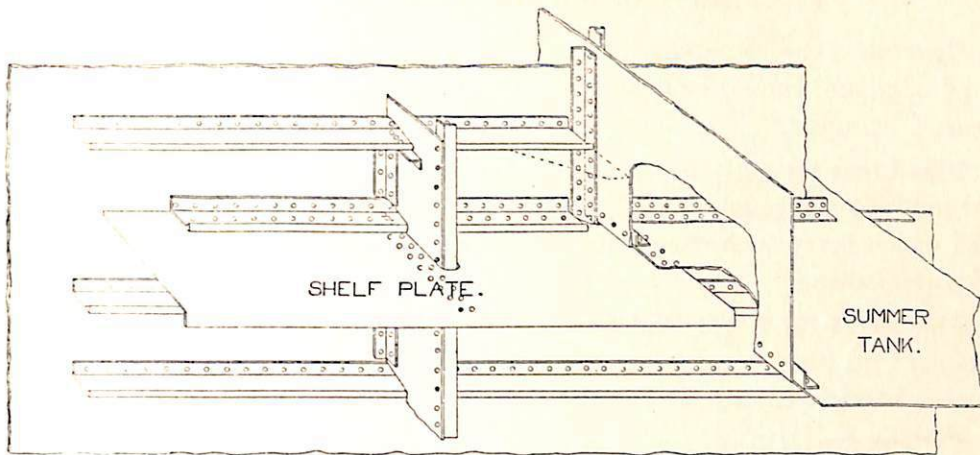
Forward of the forward cofferdam, the frame spacing must not exceed 27 inches and web frames, with side stringers, must be fitted not more than 4 frame spaces apart. Panting beams and stringers must be fitted in the fore peak, as in all ships.

The three strakes of bottom plating next to the keel must be thickened in the pounding region, as in all ships. In this region, if the ship is welded, additional intermediate transverses are to be fitted. If the longitudinals are riveted to the shell plating, they may have back bars, in lieu of this.

FRAMING AT THE AFTER END.

If transverse framing is used abaft the cargo tanks, web frames must be fitted not more than 5 frame spaces apart; whilst strong beams must be introduced in the machinery openings. Under the deck the longitudinals must extend into the poop for a distance equal to one third of the ship's breadth.

Panting beams and stringers must be fitted in the after peak, as in all ships.



TRANSVERSE BULKHEAD.

PUMPING AND PIPING ARRANGEMENTS.

General.—The pumping and piping arrangements for a tanker are complicated and cannot be dealt with in detail here. Some general rules may, however, be noted.

Pipe Lines for Oil.—Pipes which carry cargo oils, such as vegetable oil, must not be led through oil fuel tanks ; nor may oil fuel pipes be led through tanks which carry such cargo oils. Oil pipes must not be led through boiler feed water tanks.

Pipe Lines for Fresh Water.—The pipes leading to compartments used for boiler feed water must be entirely separate from those used for oil or dirty water and they are not to be led through tanks which contain oil.

Cofferdams.—Oil compartments must be separated from fresh water tanks by a cofferdam : also oil fuel compartments from those carrying vegetable oils.

Ventilating Pipes.—Pipes are fitted to allow gas to escape from the tanks and these are often led to the masthead.

If the ship is to carry oil which has a flash point of less than 150° F., these pipes must be fitted to the hatchways. They must lead up the mast to a point above the navigation lights and their outlets must be covered with wire gauze or safety heads.

Pipes for Steam Heating.—Steam coils are necessary in tanks which may contain heavy oils, in order to heat them in cold weather. These coils must be made of wrought iron or steel and great care must be taken to ensure that they are tight. Their exhaust drains must discharge into an observation tank so that any oil which might leak into them will be seen.

Oils of low Flash Points.—A number of special arrangements must be made if the oil to be carried has a flash point of less than 150° F. The cargo oil pipes must not pass through ballast or oil fuel tanks, nor through compartments outside the oil fuel system. Cofferdams must have sounding and air pipes in them, whilst ullage plugs, or some similar arrangement, must be provided for each tank.

TESTING.

In new ships, the tanks and cofferdams are tested by a head of water of 8 feet above their highest point, excluding the hatchways. Subsequent tests are made by filling them to the top of the hatchway.

Bunker and peak tanks are tested in the same way as in ordinary cargo ships.

Notes.

SECTION III.
SHIPYARD PRACTICE.

PRELIMINARY DRAWINGS.

Before a ship can be built, drawings must be made showing the main details of her outline and construction. The first ones prepared are as follows :

The Sheer Plan.—This is an elevation which shows the fore and aft outline of the ship, the contour of the stem and stern, the sheer of the decks, the arrangements of superstructures, etc. It also shows the positions of the waterlines which are drawn on the half-breadth plan and of the sections which are shown on the body plan. It is sometimes called the “Profile.”

The Half-Breadth Plan.—This shows the shape of the upper deck and of the various waterplanes as they appear in plan.

The Body Plan.—The body plan shows the shape of the sections which are marked on the sheer plan. The forward sections are shown on the right hand side and the after ones on the left hand side. A number of other details are also shown on this plan, the principal ones being :—

The positions of the landing edges of the shell plating.

Bevel lines, which give the bevel required for the frames.

Ribband lines, which show the positions in which the ribbands will be placed when the frames are in position.

The positions of side girders, tank tops and tops of floors, margin plates, tank side brackets, decks, panting stringers and any other stringers that may be fitted.

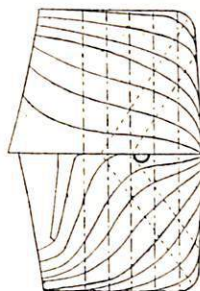
The shape of the transom floor and the positions of the cant frames on it.

THE HALF BLOCK MODEL.

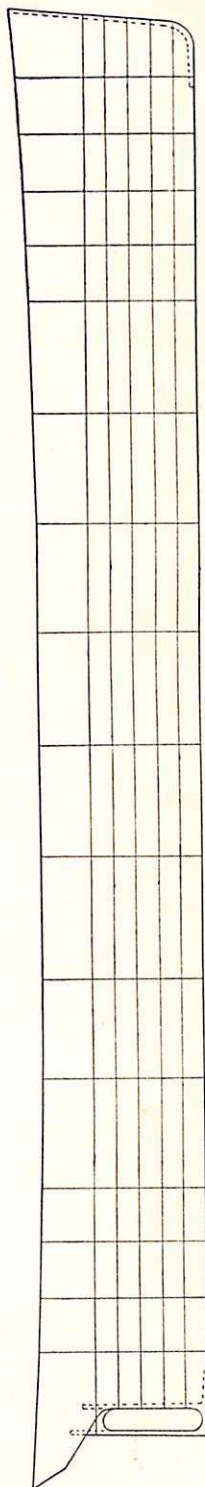
A wooden model is usually made from the above drawings on a scale of $\frac{1}{4}$ inch to the foot, and this is known as the half block model. It allows the builder to determine the exact length of plates, etc. The positions of frames, plate edges, bulkheads and openings in the sides are usually shown on the model—these being necessary to enable the shipbuilder to decide how to place the butts of the shell plating so that they shall be clear of obstructions.

THE MOULD LOFT AND FAIRING THE BODY.

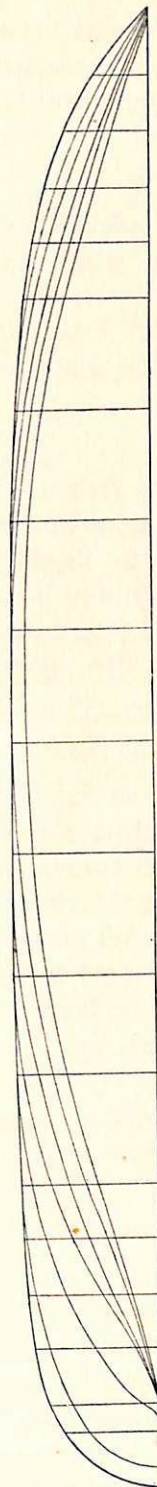
The lines shown on the drawings are next drawn full size on a large wooden floor, known as the “mould loft.” It is often found that there are



BODY PLAN.



SHEER PLAN.



HALF BREADTH PLAN.

DRAWINGS.

small discrepancies between the lines of the body plan and those of the half-breadth plan. These are adjusted during the laying off in the mould loft, the process of adjustment being termed "fairing the body."

THE SCRIVE BOARD.

The completed body plan is transferred from the mould loft to the scrieve board, which is a large wooden floor close to the bending slabs. The lines are cut-in on this board and coloured with paint so that they can be distinguished. From these lines the men who are bending the frames can determine their shape and bevel and the position of the rivet holes in them.

THE KEEL BLOCKS.

Slope and Height.—The average slope of the keel blocks is $\frac{5}{8}$ inch to the foot. If the slope of the ground is the same as that of the blocks, the latter will be the same height fore and aft; if not the forward blocks will be built up. The minimum height of the blocks should be about 4 feet 6 inches in order to facilitate riveting under the bottom of the ship. The blocks are spaced about 4 feet apart so that the workmen can pass easily between them.

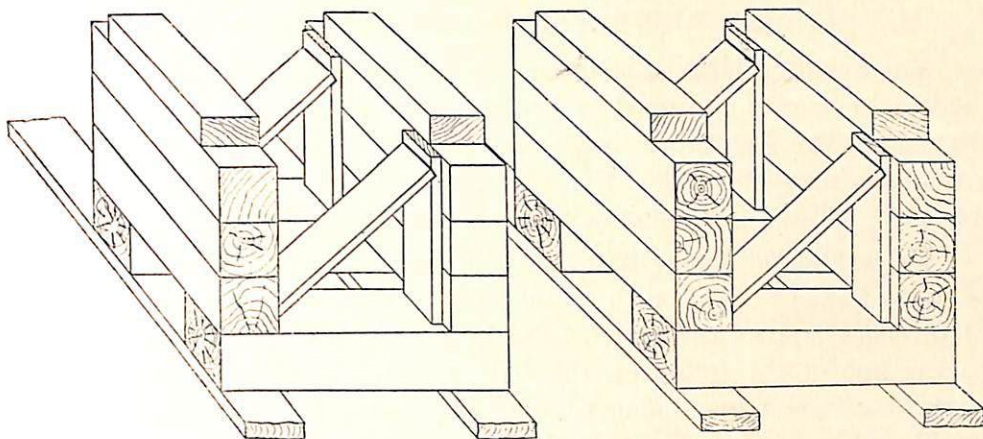
Drawings.—A sketch is prepared in the drawing office showing the positions of the blocks on the slip and their height and spacing.

Laying and Fairing the Blocks.—Heavy piles, about 15 inches square, are driven into the ground under the line of the blocks, and cross logs or planks, called "ground ties," are laid on top of them to take the keel blocks. The two lowest blocks are often laid fore and aft with a set of transverse blocks laid on each end of them. The height of various blocks, at short distances apart, is measured from the drawings and set up on the slip. A wire is then stretched across these and the intermediate blocks set up to it.

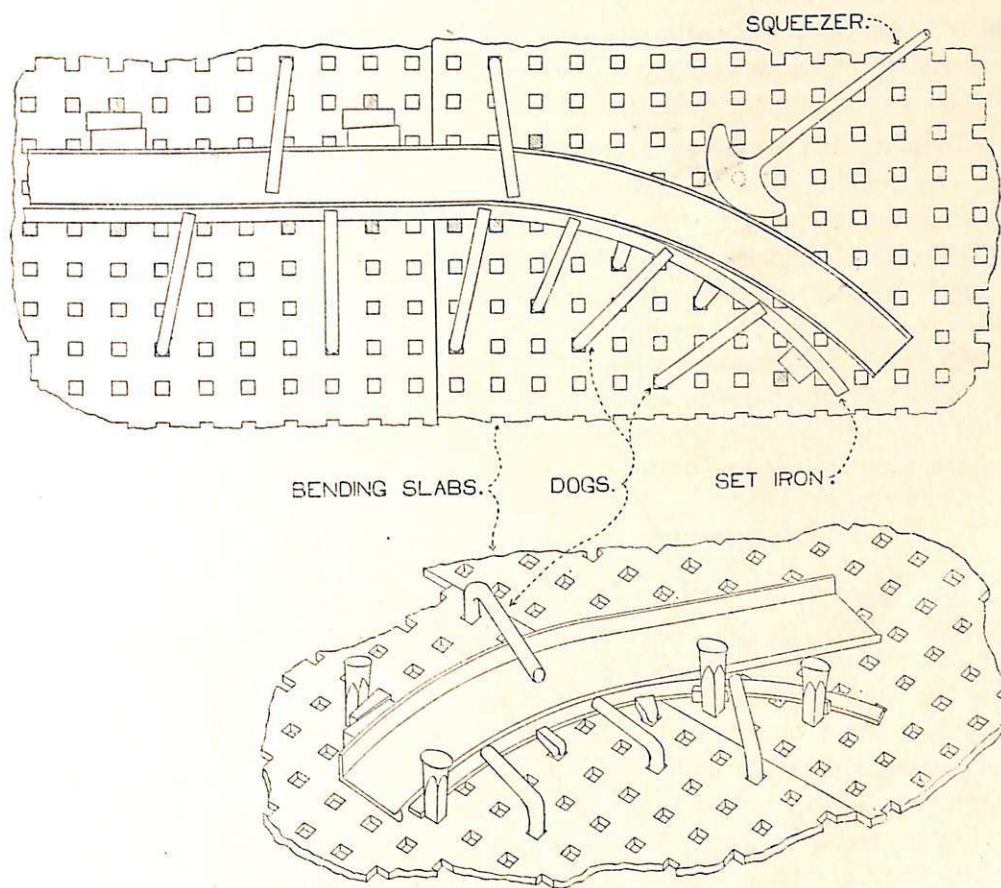
The blocks are usually baulks of pine timber, and when the keel is in place long tapered hardwood wedges are driven in between two of them. They are often kept from tripping (i.e. falling over in a fore and aft direction) by means of fore and aft tie planks and diagonal shores.

LAYING THE KEEL AND BOTTOM.

After the blocks have been set up the keel and centre girder are laid on them. The floors are then attached and are shored up at their outer ends and supported by ribbands, i.e., wooden timbers, 40 feet to 50 feet long and 4 inches to 6 inches square. The intercostal girders in the bottom are then fitted and are usually followed by the inner bottom plating, although in some yards the outer bottom is erected first. After the margin plate is in place, the erection of the frames can be commenced.



KEEL BLOCKS.



FRAME BENDING.

BENDING AND BEVELLING FRAMES AND BEAMS.

The Bending Slabs.—The frames and beams are received from the makers in straight lengths and must be bent to shape before they can be fitted into the ship. The frames are bent on "bending slabs," which are large iron gratings into which can be fitted short, curved iron bars, called "dogs" and iron pins. Beams are bent cold in a machine to give them the right camber.

Preparation of Frame Bars.—Before the frame is bent, most of the rivet holes are punched in it, with the exception of those in the way of deck and plate edges and at the turn of the bilge. A thin wooden batten is bent to the line of the frame on the scribe board and the positions of plate edges, etc., are marked on it. The batten is then straightened and the markings transferred to the frame bar, on which the rivet holes are marked and punched-in.

The Set Iron.—The set iron is an iron batten, about 1 inch by $\frac{1}{2}$ inch, which is heated and bent to the shape of the frame. It is then taken to the bending slabs and fastened down on them by dogs and pins to form a pattern for the bending of the frame.

Bending and Beveling Frames.—The frame bar is heated in a furnace near the bending slabs and, when hot, it is transferred to the slabs and first bevelled and then bent.

Beveling is sometimes done by hand, a special beveling lever being used. In modern work, however, it is nearly always done by machinery, as this makes a quicker and better job.

One end of the frame is now pinned down against the set iron and the bar gradually worked round to the required curvature by means of special levers, called "squeezers." As the frame is bent it is progressively fastened in place by dogs, pins and wedges.

ERECTING FRAMES AND BEAMS.

Erecting.—After they have been bent, the frames are taken to the building slip and erected, the upper deck beams being temporarily attached to them as soon as they are in place. It is usual to erect the after ones first and then to carry the work on towards the fore end of the ship.

When the after frame has been erected its upper end is supported by shores and guys and the ends of ribbands are bolted to it. As successive frames are erected they are bolted to the ribbands, on which their positions have been previously marked. Every fourth or fifth frame is shored up transversely, the intermediate ones being supported by the ribbands. The beams are shored-up at their middle length and ribbands are fixed on them on either side of the line of hatchways.

ERECTING FRAMES AND BEAMS.

Fairing Frames.—After a number of frames have been erected, they are “faired”—i.e., adjusted to their true position. They are first centred over the keel by hanging a plumb line from the centre of the beam and adjusting the frames transversely until the plumb-bob is directly over the centre girder. Next, they are set exactly at right angles to the keel, either by using a large square or by triangulation from a point on the keel—this operation is usually called “horning.” Finally, they are set perpendicular to the keel by means of either a special plumb-line which allows for the slope of the blocks, or by a square.

Fairing Beams.—The beams are next faired. Their centres are adjusted to the proper height by means of a batten on which the measurements have been marked in the mould loft. Then their outer ends are faired and the knees permanently fastened to the frames.

Other Operations.—The bulkheads and the stem and stern frames are erected at about the same time as the frames. After the frames have been faired, the lower deck beams are also fitted.

PLATING.

The deck and shell plating are next put on. The plates are actually made and punched from “templates,” which are skeleton frameworks of thin wood on which are shown the shape of the plate and the position of frames, rivet holes, etc.

The deck stringer plates and their stringer angles are usually the first fitted, and when they are in place the remainder of the deck plating is put on. The shell plating is generally begun with an in-strake near the bilge, and then the remaining strakes are fitted in any order that happens to be convenient. After a number of plates of adjacent in-strakes are in place, the out-strake between them is commenced.

When plates are being riveted-up, it is usual to start at the middle of each line of rivets and to work outwards. This ensures that any unfairness which may occur is reduced to the minimum possible. If the riveting were started from one end, a slight unfairness might be considerably magnified by the time the other end was reached.

FINISHING THE SHIP.

When the plating has been put on, the remaining work necessary before launching is done. This includes the fitting of pillars, deck girders, hatch coamings, the stern, hawsepipes, etc. Such work is comparatively straightforward and need not be considered here.

LAUNCHING THE SHIP.

When the ship is nearly ready for launching, the "launching ways" are set up under her. There are two sets of ways; the lower, or "fixed ways," and the upper, or "sliding ways."

The fixed ways consist of two sets of logs, one on either side of the keel blocks, spaced about one-third of the ship's breadth apart. They extend from the bow of the ship to about the low-tide mark, and consist of logs of about 2 feet in width, supported by closely spaced blocks. The declivity of the ways varies considerably with different slips and types of ships and they are usually given a slight camber down to the water. As the success of the launch depends very largely on these ways being correctly placed, careful calculations must be made before they are laid down.

The sliding ways are similar baulks of timber which extend for the length of the ship and which carry a cradle built around the vessel to support her. In most yards, they are guided along the fixed ways during the launch by baulks of timber bolted either on the inner edge of the sliding ways or on the outer edge of the fixed ways.

A day or so before the launch, the cradle is taken to pieces and the fixed and sliding ways under the ship are greased, first with tallow and then with soft soap. After this, the cradle is replaced and special shores, known as "dog shores" or "daggers" are set up to fix the sliding ways in position until the moment of launching. The keel blocks are not removed at this stage, and continue to carry the ship's weight until the day of the launch.

On the morning of the day on which the launch is to take place, long, thin wedges are driven in under the cradle, raising it and taking some of the weight off the keel blocks. The latter are then knocked out and the ship rests on the ways, which are kept from moving by the dog shores. The remainder of the fixed ways are now greased and a hydraulic ram is put in place to give the ship a start if she should fail to move of herself when the launch begins.

At the moment of starting the launch, the dog shores are knocked out simultaneously by a special arrangement of weights. The ship then starts to move and slides down the ways into the water.

If the ship is being launched into open water she is brought up, when clear of the ways, by letting go an anchor. A large number of launches however, take place into narrow channels, and in this case the ship must be brought up rather more quickly than is possible by the above method. To do this, cables from the ship are made fast to heavy masses of chain or plates, called "drags." These are so arranged that as soon as the ship is afloat the chains tighten, and the friction between the drags and the ground brings her up very quickly. Anchors, buried in the ground, are sometimes used instead of, or in combination with, the drags.

This completes the launch and tugs then tow the ship round to her fitting-out berth, where she is completed, engined and made ready for sea.

SECTION IV.

SURVEYS, MATERIALS, TONNAGE AND FREEBOARD.

SURVEY.

All ships are subject to certain surveys if they are to retain their Class. Those required by the Rules are Periodical Special Surveys, Surveys of Repairs, and Annual Surveys. Certain parts of the ship should also be given a brief survey on other occasions, when the opportunity occurs.

Periodical Special Surveys.—These are surveys of the general structure of the hull, etc., to ensure that the ship is in a fit condition to retain her Class. They become due at four-yearly intervals: the first, four years after the ship is built, and each subsequent one, four years after the previous survey. Since it is not always convenient for shipowners to have the survey completely carried out on its due date, it may be spread out over a limited period, if desired. It must not, however, be spread out over more than twelve months and must always be completed within six months of becoming due.

When a ship has passed any of these surveys, the fact is noted in the Register Book.

First Periodical Special Survey.—For this and for all subsequent special surveys, the ship must be put into drydock, or on to a slipway and the holds, peaks and bunkers must be cleared for examination. When a ceiling is fitted in coal bunkers or over the inner bottom, some of this must be lifted so that the plating under it can be examined. If this is found satisfactory, the remaining ceiling need not be lifted.

The bilges, limbers and all other steel work of the ship must be cleaned and exposed for the surveyor's examination. If he thinks it necessary, the surveyor may have holes bored in any part of the ship in order to determine the thickness of the plating.

Tanks not used for oil fuel must be examined internally, but if the bottom is covered with cement or asphalt, this need not be removed if it is in good condition. Fore peak and after peak tanks must be examined internally, whether used for oil fuel or not, but any other tanks used for oil fuel need not be so examined.

Double bottom tanks used for water ballast only, must be tested by a head of water to the light water line or to 8 feet above the inner bottom, whichever is the greater. If used for fuel oil, they must be tested by a head of water to the load water line or to the maximum head which can come on them in practice, whichever is the greater.

Peak tanks and deep tanks used for water ballast are tested by a head of water of at least 8 feet above the crown of the tank. If used for oil fuel, they are tested by a head of 8 feet above the crown of the tank or the maximum head that can come on them in practice, whichever is the greater.

The steering gear and all its connections, spare parts and telemotor gear, if any, must be examined. Rod and chain steering gears must be cleaned and given special attention.

Hatch covers and supports must be examined when in place in the hatch, and tarpaulins, cleats, battens, etc., must be surveyed. Ventilator coamings and covers must be given special attention.

Masts, spars, rigging, equipment, anchors, windlass, pumps, watertight doors, air pipes, sounding pipes and doubling plates under sounding pipes are to be examined.

The freeboard is to be verified.

Subsequent Special Surveys.—At every special survey after the first, all the above requirements are to be carried out and also the following :—

The ceiling in the holds must be removed as necessary to make possible the examination of parts of the tank top, feet of stanchions and the bottom plating of bulkheads and tunnel. If the surveyor thinks it necessary, he may require the whole ceiling to be removed.

All tanks, including oil fuel bunkers, are to be cleaned out so that they may be examined internally.

Anchors and cables must be ranged and put in good order, and the chain lockers examined internally.

Surveys After 10 Years.—At every survey, after the ship is ten years' old, the following requirements are to be carried out, in addition to the above :—

The cement chocks at the sides of the ship must be examined and parts of them removed so that the steelwork under them can be seen. All ceiling in coal bunkers must be lifted in order that a thorough examination of the deck may be made. Mast wedging is to be taken out.

Surveys After 24 Years.—At the first special survey after the ship is 24 years' old and at 12-yearly intervals thereafter, the following requirements are to be added to the above :—

The insides of bunkers and of parts in the vicinity of the boilers are to be given special attention.

Holes are to be drilled in the shell plating in order to ascertain its thickness. At least one hole must be drilled about amidships and one in the vicinity of each peak bulkhead in every strake which is not covered with cement. Bottom plates which are covered with cement need not be drilled if the surveyor is otherwise satisfied.

Survey of Repairs.—All repairs must be carried out under the supervision of the Surveyors if this is possible. If the ship is repaired at a port where there is no Lloyd's Surveyor, the survey must be carried out at the earliest possible opportunity.

Annual Surveys.—All ships should be examined in drydock at intervals of about a year : these surveys should, if possible, be held at the same time as the freeboard surveys.

The ship must be examined externally and internally, as necessary. Special attention must be given to hatchways, ventilators, casings and superstructure bulkheads, openings in the shell plating, windlass, rudder and steering gear.

Occasional Surveys.—Certain parts of the ship, which are not normally accessible, should be examined whenever the opportunity occurs.

If cement is removed in the bottom, the plating under it should be examined before new cement is laid. If engines or boilers are removed, the structure under them must be surveyed.

Whenever the ship is in drydock, the propeller and stern bush and the outsides of machinery and boiler inlets must be examined, whilst the wear down of the stern bush should be measured.

TESTING OF MATERIALS.

All steel which is to be built into a ship must be tested at the place where it is manufactured and then stamped with a special mark authorised by the Society. Test pieces of certain standard dimensions are to be used for this purpose.

Tensile Tests for Plates.—The tensile breaking stress for ordinary steel plates must be between 26 and 32 tons per square inch, unless they are to be cold-flanged, when it may be between 26 and 30 tons per square inch. The elongation of the test pieces is to be not less than 20 per cent for steel of $\cdot 375$ inch and upwards in thickness, or 16 per cent. for thinner steel.

Tensile Tests for Angles, Channels, Etc.—Angles, bulb-angles, channels and similar sections must have a breaking stress of between 26 and 32 tons per square inch. If they are to be used for a purpose for which tensile strength is not important, however, they need not be tested. The elongation must be the same as for plates.

Bend Tests.—All steel, except rivet bars, is liable to bend tests. Steel which will have to be worked or flanged in a fire, or which will be subject to fire when in use, must be tempered before testing by being heated to a blood red colour and then plunged into water having a temperature of not more than 80°F. Other steel need not be tempered.

The test is made by bending the piece of steel, either by blows or by pressure, back upon itself, until the sides are parallel and the internal radius of the bend is $1\frac{1}{2}$ times the thickness of the metal. It must then show no sign of fracture.

Tests for Rivet Bars.—The bars from which rivets are made are to be tested before being manufactured. Steel bars are to have a tensile strength of between 26 and 30 tons per square inch, with an elongation of 25 per cent. for a test piece having a length of eight times the diameter of the bar. Iron bars are to have a tensile strength of from 21 to 25 tons per square inch. The elongation on a similar test piece to the above is to be 22 per cent. for wrought iron bars or 25 per cent. for ingot iron bars. Wrought iron bars must also be nicked with a sharp cutting tool and then bent at the nick through 180°. They must then show a clean, fibrous type of fracture, free from impurities.

Tests for Rivets.—Rivets are to be tested after they are manufactured. The shanks are to be bent cold and hammered until the two parts touch, when they must show no fracture at the outside of the bend. When hot, the rivet heads must be flattened out until their diameter is $2\frac{1}{2}$ times that of the shank, without cracking at their outer edges.

Steel Castings.—Steel castings must have a tensile strength of between 26 and 35 tons per square inch, with an elongation of not less than 25 per cent.

Test pieces of standard dimensions are to be taken and bent cold through an angle of 180° , without fracture, the internal radius of the bend being not greater than 1 inch.

Stern frames which are cast in one piece are to be raised through an angle of 45° and then allowed to fall on to hard ground—excavations being made to take projections on the casting. Stern frames cast in more than one piece, and other castings, are to be dropped on to hard ground from a height of between 7 and 10 feet, according to their nature. Complex castings, which might be deformed by this treatment are exempted from the above tests, provided that two tensile and two bend tests are made on test pieces taken from as near the top and bottom of them as possible.

After the above tests have been made, the castings are to be hung up and tested by hammering them with a sledge hammer weighing at least 7 pounds.

Large steel castings are to be further tested by drilling holes in them at all places where there is likelihood of flaws—such holes afterwards being filled up by tapping-in plugs.

Ingot Steel Forgings.—Forgings which do not need to be welded are to have a tensile strength of between 28 and 40 tons per square inch, whilst the sum of the figures representing the tensile strength and the percentage of elongation must be at least 57.

Forgings which are to be welded may have a tensile strength of between 22 and 26 tons per square inch, with an elongation of between 31 per cent. and 35 per cent.

Test pieces are also to be bent cold through 180° without fracturing the internal radius of the bend being not more than $\frac{1}{4}$ inch.

CLOSING APPLIANCES.

General.—The tonnage and freeboard of ships are affected by the nature of the appliances, if any, used to close openings in the end bulkheads of superstructures. These “closing appliances” may be of one of two classes.

Class I Appliances.—These are of iron or steel, and are permanently attached to the bulkhead. The means of closing them must be permanently attached and they must be arranged so that they can be secured from either side, or from the deck above. The openings must have sills of at least 15 inches high. Hinged or sliding watertight doors, or portable plates secured by bolts passing through the bulkhead, are examples.

Superstructures enclosed by Class I appliances are normally considered to be permanently enclosed for tonnage and freeboard purposes.

Class II Appliances.—These may be of three types :—

- (a) Strong hardwood doors, hinged to the bulkhead and not more than 30 inches wide, nor less than 2 inches thick.
- (b) Shifting boards, fitting into channel bars, riveted to the bulkhead.
- (c) Portable steel plates, fastened by strong backs or by hook-bolts which do not pass through the bulkhead.

Superstructures enclosed by Class II appliances are generally considered to be temporarily enclosed for tonnage and freeboard purposes.

TONNAGES.

General.—Tonnages are measures of volume, expressed in terms of 1 ton per 100 cubic feet of space. They may broadly be described as a method of assessing the approximate earning-power of a ship.

Gross tonnage consists of all enclosed spaces in the ship, with certain exemptions. Nett tonnage is found by making certain deductions from Gross tonnage.

Tonnage Deck.—The tonnage deck is the upper deck in single decked ships and the second deck from below in all others. It is chosen arbitrarily, for convenience in measuring the ship for tonnage.

Gross Tonnage.—This consists of the sum of four things :—

- (a) The whole volume of the ship below the tonnage deck, measured inside the frames and above the top of the floors or inner bottom. This is sometimes called "Under Deck Tonnage."
- (b) The cubic capacity of all spaces in the 'tween decks, between the tonnage deck and the upper deck.
- (c) The cubic capacity of all permanent closed-in spaces above the upper deck, if these are available for cargo or stores or for the berthing or accommodation of passengers or crew. Spaces above the upper deck which are not permanently enclosed and not fitted for the berthing or accommodation of passengers are exempted from this, however : as are also spaces used solely for the shelter of deck passengers.

Poops, bridges, forecastles and shelter decks are exempted, as above, provided that they comply with certain requirements, which are described later.

Closed-in spaces used solely for machinery, the wheelhouse, cookhouses and bakeries, condenser spaces and most W/Cs are also exempted, however enclosed.

- (d) "Excess of Hatchways," which consists of any space within the hatchways in excess of one-half per cent. of the sum of (a), (b) and (c), above.

Double bottom tanks are not included in gross tonnage. When they contain fuel, stores or cargo, however, they are temporarily added to that tonnage.

When deck cargo is carried by a foreign-going ship, it is measured and forms a temporary addition to the gross tonnage. This does not apply to home-trade ships.

If cargo or stores are carried in an exempted space, that space is also temporarily added into tonnage.

Nett Register Tonnage.—An “Allowance for Propelling Power” and the full volume of certain spaces in the ship are deducted from the gross tonnage to give nett tonnage.

The propelling power spaces consist of the engine and boiler rooms, light and air and machinery spaces above them, shaft tunnels and trunked escape ladderways. If the volume of these is between 13 per cent and 20 per cent. of the gross tonnage, 32 per cent. of the gross tonnage is deducted as allowance for propelling power. If the volume is less than this, the deduction is $1\frac{3}{4}$ of the actual propelling power spaces: if more, the deduction may be either of the above, as agreed between the Ministry of Transport and the Shipowner. The allowance may not, except in the case of tugs, exceed 55 per cent. of the tonnage which remains after all other deductions have been made.

Spaces used exclusively for working the helm, capstan and anchor gear, chart rooms, wireless spaces, the boatswain's store, donkey engine and boiler space, water ballast spaces and Master's and Crew's spaces are deducted in full; subject to certain requirements and provided that they have previously been included in the gross tonnage. A notice must be placed above them to indicate their purpose and goods or stores, other than those for which they are intended, must not be carried in them.

Superstructures.—Poops, bridges and similar permanent erections are only exempted from gross tonnage if they have two openings in the end bulkhead, at least 3 feet wide and 4 feet high; or one opening of at least 4 feet wide and 5 feet high; with coamings of not more than 2 feet high. Provided that these openings are either not closed, or have only temporary means of closing.

Shelter Decks.—These are exempted from gross tonnage if they comply with certain requirements.

They must have a tonnage opening in the middle line of the deck, at least 4 feet long and as wide as the after hatch. This opening must not be within one-twentieth of the ship's length from the sternpost, nor one-fifth of the length from the stem. Its coamings must not be more than 12 inches high and it must have guard rails and stanchions, but no means of battening down. It may have wooden hatch covers, provided that these are secured only by hemp lashings from below.

There must be two openings in each transverse bulkhead within the shelter deck, similar to those required for the end bulkheads of superstructures.

One 5 inch scupper, with a screw down, non-return valve, geared to the shelter deck, must be fitted on each side of the upper deck in the way of the tonnage opening.

Means of closing and battening down all openings in the upper (freeboard) deck must be provided.

FREEBOARD.

General.—A ship is assigned a freeboard for three purposes : to ensure that she cannot be loaded beyond her strength : to provide her with adequate reserve buoyancy : and to keep the decks high enough from the water to enable the crew to navigate and handle her in all weathers.

If this is to be achieved, it is important that all openings in the freeboard deck should be properly protected and closed and that provision should be made to allow the ship to free herself quickly of water which may come in upon the decks. To ensure that this is done, the ship is required to comply with certain "Conditions of Assignment" and is not granted a loadline unless she does so.

Conditions of Assignment.—The height and stiffening of hatch coamings and the construction of hatch covers, carriers, cleats and locking bars must be as mentioned earlier in this book (See pages 130 to 134). There must be at least two good tarpaulins per hatch.

Machinery space openings must be properly framed and constructed; whilst doors in them must comply with certain requirements.

Ventilators must have coamings of a given height, with means of closing them. They must be properly supported and the deck must be stiffened around them (See page 148).

If air pipes extend to above the freeboard deck, they must be of a certain minimum height (See page 152) and must have efficient means of closing.

Openings in the ship's side, below the freeboard deck, must have efficient watertight doors or covers. Side scuttles below the freeboard deck, or in enclosed superstructures, must have inside deadlights.

Discharges from spaces below the freeboard deck, or within enclosed superstructures must have either one non-return valve with positive means of closing from above the freeboard deck, or two such valves without such means of closing. Valves which are attached to the ship's side must not be of cast iron.

Freeing ports on well decks must have a minimum area which depends on the length of the well and two-thirds of this area must be in the midship half of the well deck. On superstructure decks, the area must be equal to half that required for freeboard decks. The freeing ports must be constructed as described on page 92.

Principles of Assignment.—In the first instance, the ship is assigned a “Basic Minimum Freeboard,” on the assumption that she conforms to certain standards of strength and form. The amount of this freeboard depends on the length of the ship: for example, it is 71·5 inches for a ship of 400 feet long, and 102·3 inches for a ship of 500 feet long.

If the ship's strength or form differ from the standards laid down, the freeboard is adjusted accordingly. It is also decreased if the ship has superstructures or trunks, or increased if she is flush decked.

Adjustments for Strength and Form.—These are briefly as follows:—

Strength.—The standard of strength is that required by the highest rules of a recognised classification society. If the ship's strength is less than this, the freeboard is increased.

Proportion of length to depth.—If this exceeds 15, the freeboard is increased.

Coefficient of fineness.—The freeboard is increased if the coefficient exceeds 0·68.

Round of beam.—If the actual round of beam is greater than the standard of one-fiftieth, the freeboard is decreased. If it is less than the standard, the freeboard is increased.

Sheer.—A line parallel to the keel, is drawn so as to touch the upper deck amidships. The area between this line and the deck is called the “sheer profile.” The standard and actual sheer profiles are compared and if the ship has an excess of sheer, the freeboard may be decreased, subject to certain conditions. If the ship has a deficiency of sheer, the freeboard is increased.

Adjustments for Superstructures.—If the ship is flush decked, the freeboard is increased by $1\frac{1}{2}$ inches for every 100 feet of her length. This is often called “the flush deck penalty.”

If the ship has superstructures, the freeboard is decreased by an amount which depends on the nature and length of the superstructures, the type of closing appliances used, and the length of the ship.

Freeboard for Tankers.—These are assigned on the same principles as those for ordinary ships, except that the basic minimum freeboard is less and the allowance for superstructures is greater than normal. A winter North Atlantic freeboard must also be assigned and the ship must also comply with certain supplementary conditions of assignment.

Supplementary Conditions of Assignment for Tankers.—A forecastle of standard height and length of 7 per cent. of the ship's length must be fitted.

Machinery casings must be encased in a poop, or equivalent deck house. All openings on freeboard decks must have steel doors and the fiddley openings must have steel covers permanently attached.

Hatchways must have steel covers.

A permanent gangway must be fitted fore and aft at superstructure deck level, between the bridge, machinery spaces and crew's quarters, unless some equivalent means of access are provided.

Ships with bulwarks must have open rails for at least half the length of the exposed parts of the weather deck. If the ship has trunks, connecting the superstructures to each other, open rails must be fitted for the whole exposed length of the weather deck.

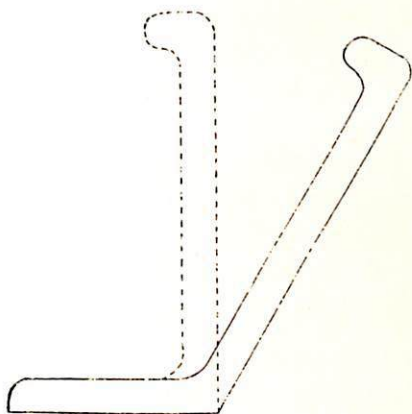
SECTION V.
DEFINITIONS.

DEFINITIONS.

Base Line.—This is an imaginary horizontal line, drawn through the upper edge of the keel, from which rise of floor, etc., may be measured.

Bending Moment.—The measure of the tendency of a beam to bend about any particular section is called the “Bending Moment” at that section. It is found by taking the algebraic sum, at any point on the section, of all the forces acting on either side of the beam.

Bevelling of Frames.—The frames must always be at right angles to the fore and aft line. Towards the ends of a ship the sides do not run parallel to this line, but come together at an angle. This means that the two flanges of the frame cannot be at right angles, since one must be in the athwartships line, whilst the other must fit closely to the shell plating. The frame angles must, therefore, be opened out at an angle other than a right angle, and this is termed “bevelling” them. For convenience in riveting, the shell flanges are made to point aft in the fore part of the



ship and forward in the after part, so that the bevel is always obtuse, i.e., more than 90° .

Break.—This is the end of a superstructure. For example, the “break of the forecastle head” is at the after end of the forecastle, where it drops away to the upper deck. Special care is needed at breaks to preserve continuity of strength.

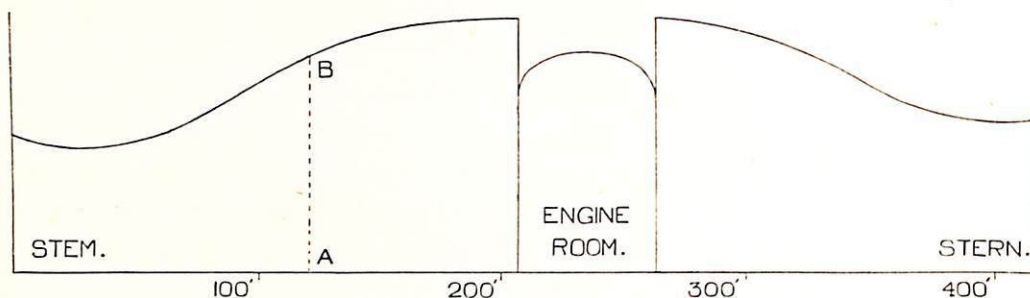
Bridges.—The term “bridge” when used in ship construction, refers to a superstructure amidships which is part of the hull, not to the deck house carrying the navigating bridge.

A “long bridge” is one having a length of more than 15 per cent. of the length of the ship. A “short bridge” is one which is shorter than this.

Bulkhead Spacing.—In passenger ships, this is governed by the “permissible length,” which is the “floodable length” multiplied by the “factor of subdivision.”

The “factor of subdivision” is a number, found by formulae, which depends on the ship's length, her volume below the margin line, the volume of the machinery spaces, the volume of passenger and crew spaces below the margin line, and the number of passengers she is intended to carry.

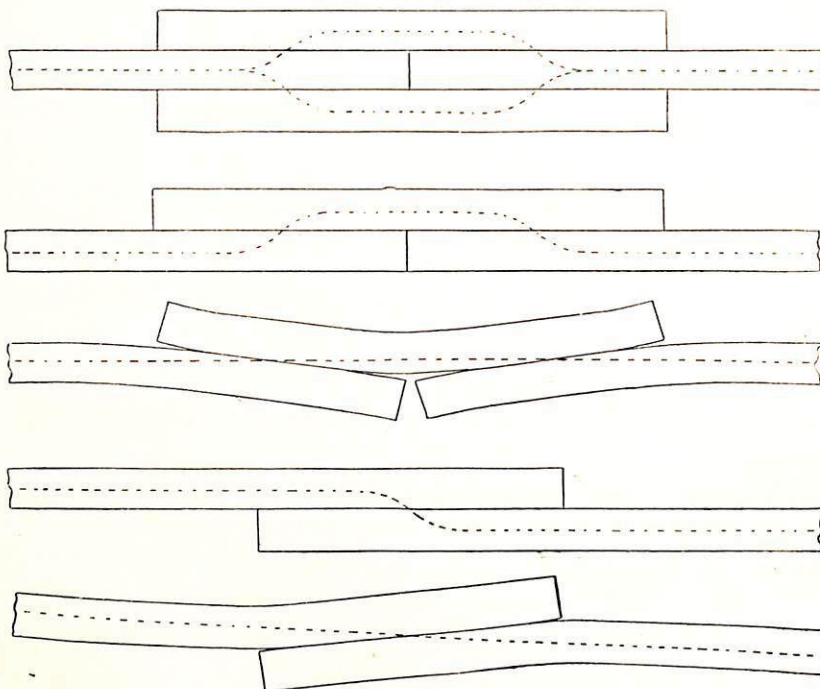
The “margin line” is an imaginary line, 3 inches below the bulkhead deck at the ship's sides.



The "curve of floodable lengths" is a graph. The lower side represents the ship's length from stem to stern. The vertical side represents the floodable length—i.e., that length of the ship which, if flooded, would sink her to the margin line. The curve itself shows the floodable length for any part of the ship, assuming that the point at which it is taken is the middle of a compartment.

The sketch shows an example of such a curve. Suppose that in the case shown we wish to find the floodable length at a distance of 120 feet from the stem. We draw a perpendicular at that point and the length from the base line to the curve (*AB* in the sketch) is the required floodable length.

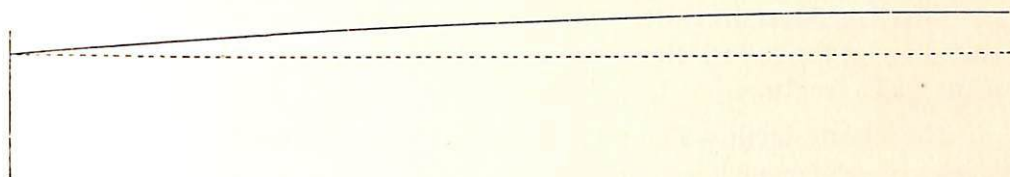
Butts and Laps.—Strength is of considerable importance in "butts" and "laps," particularly when they form end joints. The dotted lines in the diagrams show the lines of strength, which try to straighten themselves when the joint is put under stress.



Double-strapped joints are very efficient and do not tend to open under stress.

Single-strapped joints are not very efficient, as they tend to open under stress. This is shown by the accompanying sketches.

Lapped joints tend to become slightly deformed when under stress, but have not the same tendency to open up.



Camber.—This is the athwartships curvature of decks, which rise from the sides towards the centre line. The usual camber is $\frac{1}{4}$ inch rise in 1 foot of width.

Carlings.—These are short fore and aft girders, fitted under a deck where extra stiffening is required. They are often found under winches, bollards, etc. Mast partners are a form of carling.

Centre Line.—The centre line is the vertical plane running fore and aft through the centre of the ship.

Chain Plates.—These are eyeplates, attached to the upper edge of the sheerstrake or to the deck stringer, to which the rigging is made fast.

Cofferdam.—The name given to the space between double transverse bulkheads, spaced at least 3 feet apart, used to isolate tanks and holds from each other.

Continuity of Strength.—A ship, like a chain, is as strong as its weakest part. It is useless to make one part very strong if an adjacent part which has to resist the same stresses, be weak, Hence it is of the utmost importance that continuity of strength be maintained.

When material has to be cut away, compensations must be made to preserve continuity of strength. Square corners should be avoided as far as possible, since it has been found that these are always a source of weakness. For example, the side plating at the breaks of well decks is always run away in a curve—if it were kept square there would be a tendency for it to crack at the corners.

Parts which are very strong, by comparison with neighbouring parts, should not be allowed to end abruptly, as there would be a tendency for them to tear away where they end. They should gradually taper off and merge into the weaker parts.

Counter.—The counter is the overhanging part of an ordinary (elliptical) stern.

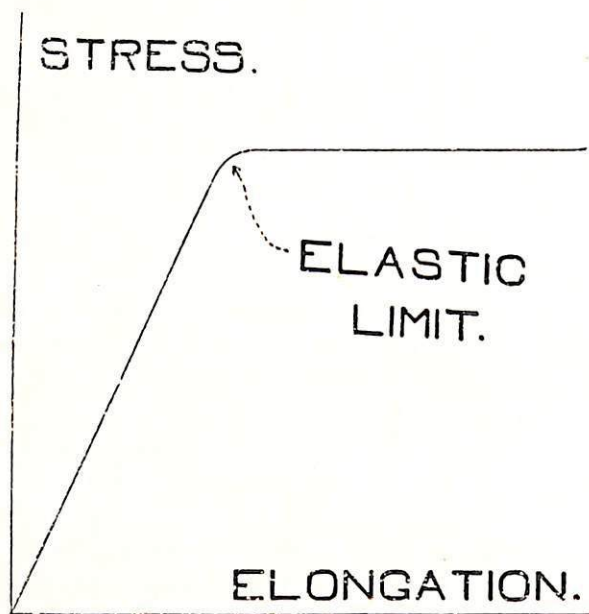
Cropping of Frames.—Cropping means the cutting away of corroded or damaged frames to let in a new piece. The cut ends should not be in the same line, as this would produce a line of weakness, but should be staggered.

Crown of a Tank.—This is the highest point of the tank-top.

Deadlights.—Metal covers, fitted inside portholes, to prevent the ingress of water if the porthole leaks, or the glass becomes broken.

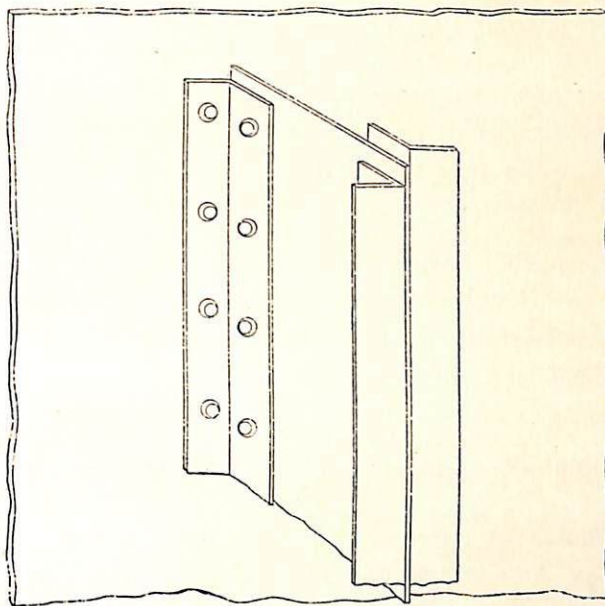
Effective Superstructure.—This is a superstructure, placed amidships, extending for the full width of the ship and having a length of more than 0.15 of the ship's length.

The Elastic Limit.—The “Elastic Limit” is that limit of stress beyond which a piece of metal loses some of its elasticity. In other words, when metal is subjected to stress it increases in length and, within certain limits, it returns to its original length when the stress is removed. A point is reached, however, at which it will not return to its original length, and this is termed the “Elastic Limit.”



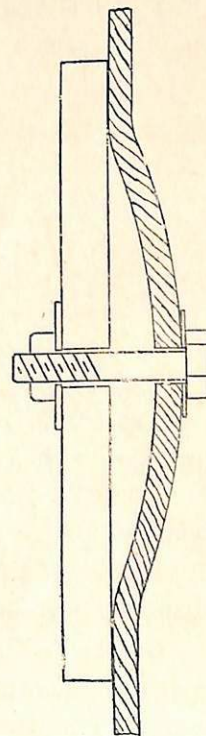
The diagram shows a graph of stress against elongation, and it will be seen that when the limit is reached, the metal stretches very rapidly for a slight increase of stress.

Face Angles.—These are stiffening angles, fitted along the inner edges of web frames, stringers, brackets, etc.



Fairing a Plate.—“ Fairing ” a plate means removing a dent from it. Small dents are often taken out by hammering. Larger ones are usually faired by boring a hole about the middle of the dent and passing a bolt through it to a strongback. The plate is then heated and the dent drawn out by screwing up the bolt. This is often called “ fairing-on.” (See diagram).

Fairing-Off.—When a plate cannot be conveniently faired-on, it may be removed and straightened by machinery in the shipyard before being replaced. The terms “ fairing-off,” or “ Off and Fair ” are often used to describe this process.



Fish Plate.—The name “fish plate” is often applied to the narrow plate which runs fore and aft along the heads of the stanchions supporting a boat deck. It might be described as a kind of sheer strake, fitted at a boat deck.

Flanging.—“Flanging” means the bending over at right angles of the edge of a plate or bracket, and is a very effective way of stiffening such an edge. It is sometimes used for making a connection to another part but is not very efficient for this purpose.

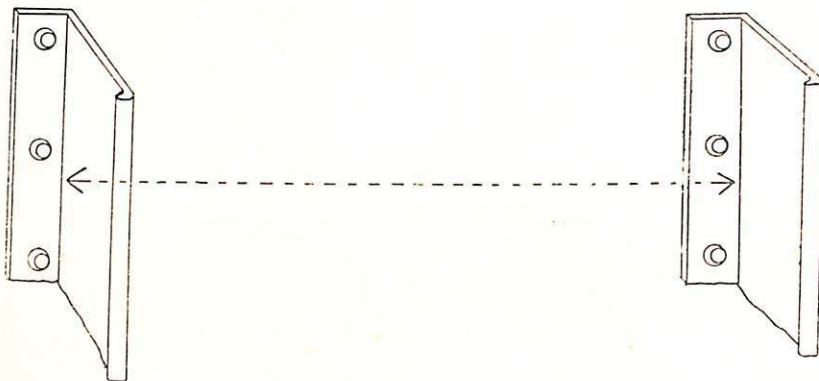
Flare.—This is the flaring-out of the bows of a ship. It helps to prevent water coming aboard and gives more width to the forecastle head. (See diagram.)



Flush Deck Ship.—Is a ship having no superstructures on the freeboard deck.

Foundation Plate.—A narrow strake of plating which runs fore and aft under keelsons, etc. An example can be seen in the sketch on Page 39.

Frame Spacing.—Frame spacing is the distance between consecutive frames, centre to centre.



Freeboard.—“Statutory freeboard” is the distance from the top of the deck line to the centre of the plimsoll mark.

The term freeboard is often taken to mean the distance from the deck line to the water.

Freeboard Deck.—The “Freeboard deck” is the uppermost complete deck with permanent means of closing all openings in its weather portions.

Gussets.—These are flat triangular plates used to connect two parts together. Common examples are those at tank side brackets and those connecting panting beams to stringers.

Hose Testing.—Hose testing is done by playing a strong jet of water from a hose, under a pressure of 30 lbs. per square inch, along a joint. If no water be forced through the joint, the latter is assumed to be watertight.

Hounds.—The fitting at the head of a mast which takes the stays, etc., is called the hounds.

Intercostals.—These are plates, angles, etc., fitted down between others, or cut to allow other parts to pass through them. Side girders in the inner bottom and lower deck stringer angles are common examples.

Landing Edges.—The edges of seams are often called “landing edges.”

Lightening Holes.—These are holes cut in non-watertight plates to reduce their weight. They must not be so large as to weaken the plate unduly.

Limber Holes.—Small holes which are cut in floors and intercostals, to allow water and air to pass from one part of a tank to another.

Load.—Load can be defined as any considerable weight or force put on a part of a ship.

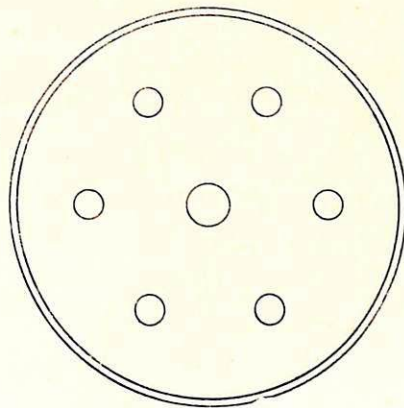
Manholes.—These are holes cut in plates in order to allow men to pass through into a compartment. They must not be confused with lightening holes, which can only be cut in non-watertight plates, whilst manholes are cut in watertight plates. Where they are cut in the latter they must have a watertight cover, which is usually bolted down by means of studs.

Non-Return Valves.—Non-return valves will, when open, allow water to flow through them in one direction only. When they are closed, no water can pass through them in either direction.

The Oxy-Acetylene Blowpipe.—The sketch shows the nozzle of this blowpipe. The inner hole gives a jet of oxygen only, the outer holes a jet of combined oxygen and acetylene. The flame given off has a temperature of about 4000°F., and is invaluable for cutting plates and for burning out rivets.

When plates are to be cut, they are made red hot by means of the combined jets and then the oxygen jet is turned on and the metal burns away. Plates of $\frac{1}{2}$ inch to 1 inch thick can be cut at from 40 to 60 feet per hour.

The blowpipe can also be used for welding, although it is not so much used for this purpose.

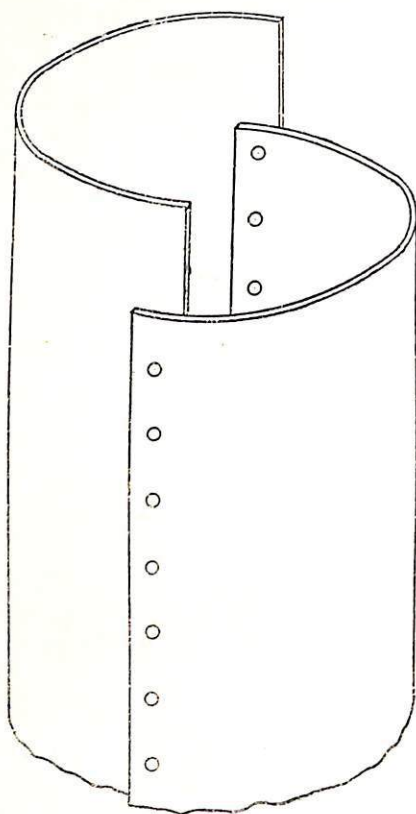


Numbering of Frames and Plates.—Ordinary frames are usually numbered from aft to forward, although in some building yards they are numbered from forward to aft.

Longitudinal frames, in ships built on the Isherwood system, are usually numbered from the deck downwards to the keel.

Plates are lettered from the keel outwards and numbered from aft.

Pitch of Riveting.—"Pitch" is the spacing of rivets, centre to centre. It is always expressed in terms of the diameter of the rivets—e.g., $\frac{3}{4}$ -inch rivets with a pitch of 6 diameters, would be $6 \times \frac{3}{4}$ -inch, or $4\frac{1}{2}$ inch apart, centre to centre.



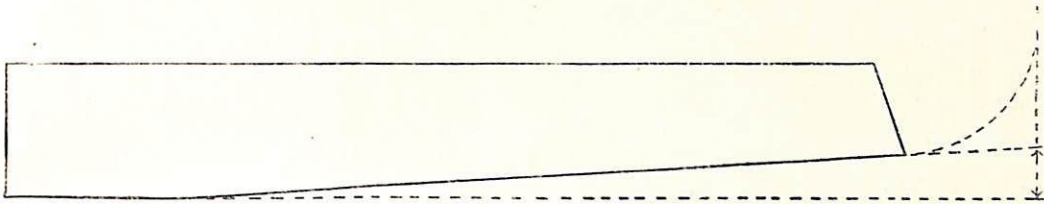
Plates on the Round.—This is the term used to denote two or three curved plates, riveted together to form a cylindrical section.

It is used largely for masts, massed pillars, etc.

Quarter Line.—"Quarter Lines" are vertical planes running fore and aft on either side of the centre line and about half way between that line and the ship's side.

Reserve Buoyancy.—This is the volume of the hull between the water line and the freeboard deck. In other words, it amounts approximately to the difference between the actual displacement and that which the ship would have if she were submerged to her freeboard deck.

Rider Plate.—A continuous plate which is sometimes fitted along the top of a keelson in order to stiffen it.

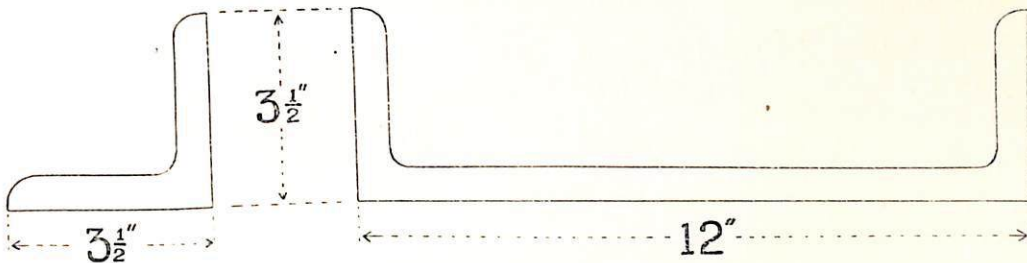


Rise of Floor.—This is the upward rise of the lower edges of the floors from the keel towards the bilges.

Scantlings.—Scantlings are the sizes of the various parts of a ship. The sketches show an angle bar and a channel section. The scantlings of these would be expressed as:—

Angle, $3\frac{1}{2}$ ins. $\times$ $3\frac{1}{2}$ ins. $\times$.36 ins.

Channel, 12 ins. $\times$ $3\frac{1}{2}$ ins. $\times$ $3\frac{1}{2}$ ins. $\times$.52 ins.



Note that, in Lloyd's Rules, the thickness of parts is given to .02 ins., i.e. to one-fiftieth of an inch.

Scarph.—A form of joint used for thick bars, etc.

Seams.—These are the joints of the longer sides of plates.

Shearing Stress.—"Shearing Stress" is the force tending to make the component parts of a structure slide over each other. In other words, it is the algebraic sum of the forces acting on either side of a section.

The shearing stresses in a ship are usually greatest at about a quarter of the length from each end, in the vicinity of the neutral axis. Note that this stress should not be confused with longitudinal bending stresses, which are least at the neutral axis and greatest at the bottom and deck amidships.

Sheer.—This is the upward rise of a ship's deck from amidships towards the bow and stern. It helps to keep the ship dry in bad weather, and also prevents the deck from becoming submerged if a forward or an after compartment become bilged.



The sketches illustrate this. Sketch A shows what might happen if a ship without sheer became flooded forward ; sketch B shows how this might be prevented by giving the ship sheer.

Shelter Decks.—" Shelter Decks " are really complete superstructures with no permanent means of closing. They may, or may not, be of the same scantlings as the lower part of the hull. They are exempt from tonnage (with some exceptions), and any cargo carried in them is regarded legally as deck cargo.

Shoring of Bulkheads.—When a compartment has been accidentally holed and is full of water, the bulkheads at either end should be shored up to help them to resist the pressure. Bulkheads which are nearly rectangular should be most strongly shored at a point about two-thirds of the depth below the surface of the water in the compartment, since the greatest stress comes at this point.

Side Scuttles.—The official name for a " porthole."

Spirkettling Plate.—This is the name given to a plate which is used to make a temporary repair when frames are badly corroded near a deck. The

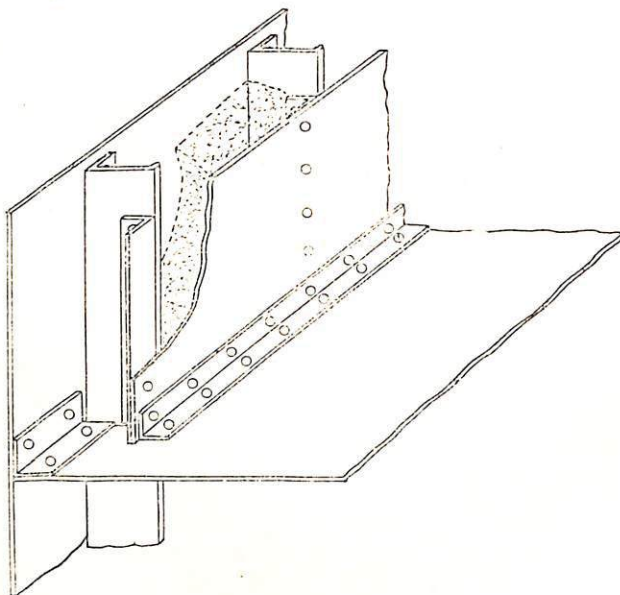


plate is attached to the inside of the frames by angle lugs and the space between it and the ship's side is filled in with cement.

Stress.—Stress is load put on a piece of material.

Strain.—Strain is distortion, or molecular disturbance, of metal due to stress.

Strength Deck.—This is the uppermost continuous deck, except in the way of an effective superstructure, where the superstructure deck is taken as the strength deck.

Storm Valves.—These are flaps, fitted at the outboard ends of scuppers, etc., which will allow water to pass outboard, but which prevent the sea water from rushing up the pipe.

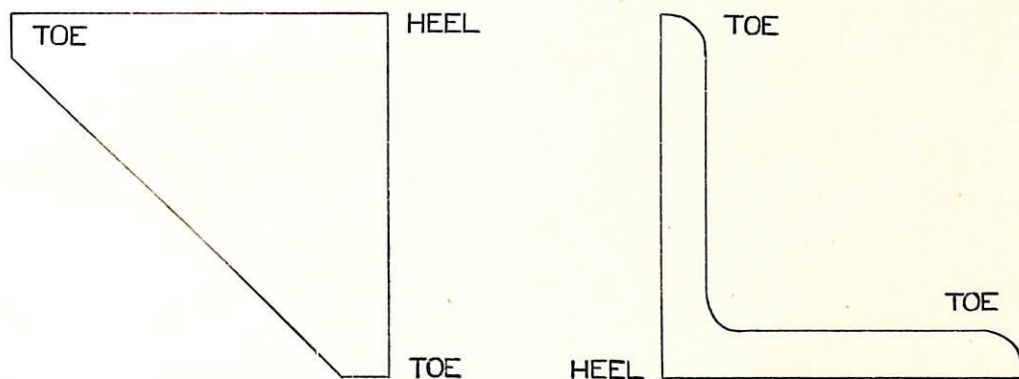
Superstructure.—This is a decked structure above the freeboard deck, extending from side to side of the ship.

Superstructure Deck.—The deck forming the top of a superstructure is called the "Superstructure Deck."

Tabernacle.—"A Tabernacle" is an arrangement of brackets, used to support a mast.

Tie Plates.—These are plates used to tie parts of the structure together when they are not otherwise directly connected to each other. They are found in many parts of a ship. The best-known form of tie plate is that fitted under a wood deck to tie the hatch coamings and masts to the beams and ship's sides.

Toes and Heels of Angles and Brackets.—The sketches show the toes and heels of an angle and of a bracket.



Tonnage Deck.—"The Tonnage Deck" is the upper deck in single decked ships and the second deck from below in all others.

Tripping of Floors.—Floors are said to be tripped when they are thrown out of the vertical. This may be caused by grounding stresses.

Tumble Home.—"Tumble home" is the falling-in of the ship's sides from the bilge towards the deck level, which allows any small projections at the deck level to clear wharves, etc. The standard tumble home is 12 inches at the strength deck.

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